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Astronomy and Astro-Physics.

NEW SERIES No. 4. APRIL, 1892. WHOLE No. 104.

General Astronomy.

ON A SIMPLE MOUNTING FOR A LARGE TELESCOPE IN THE FIELD DURING ECLIPSE OBSERVATIONS.*

PROFESSOR FRANK H. BIGELOW.

The importance of obtaining suitable observations on the phenomena exhibited by the solar corona during eclipses is becoming more pressing than ever, in the interests of the development of some branches of cosmical science. The value of any photograph of the corona depends upon the amount of structural detail that can be found on a picture of comparatively large linear dimensions. Since the diameter of the image of the Sun on the plate is a direct function of the focal length of the object glass of the camera, in order to obtain any picture in which the Sun's disk will be represented by a circle one-half inch in radius, or more, it will be necessary to mount a large telescope at the station of observations. Those who have tried it know very well the difficulty and cost of transporting the heavy mounting, the clock work and tube to the place, to say nothing of the labor of setting up the same on any proper foundations.

An attempt was made to solve this problem practically, in the late eclipse expedition to West Africa, December 22, 1889, and I propose to give in this paper an outline of the plan, in order that those preparing for the eclipse of April, 1893, may be able to avail themselves of the results of such experience. This anticipation of the regular report of the expedition is with the consent of the Director, Professor D. P. Todd.

It is not proposed at this time to consider the optical qualifications of the telescope employed, or the best focal length that should be adopted, these questions being left to the members of an expedition. The mounting to be described was applied successfully to an object glass having a focal length of nearly forty feet, and in spite of the weight of the apparatus, which was of course considerable for so long a tube, it showed that it could be

* Communicated by the author.

controlled to follow the afternoon or descending path of the Sun with a precision and steadiness seldom excelled in the best fixed instruments of a regular Observatory.

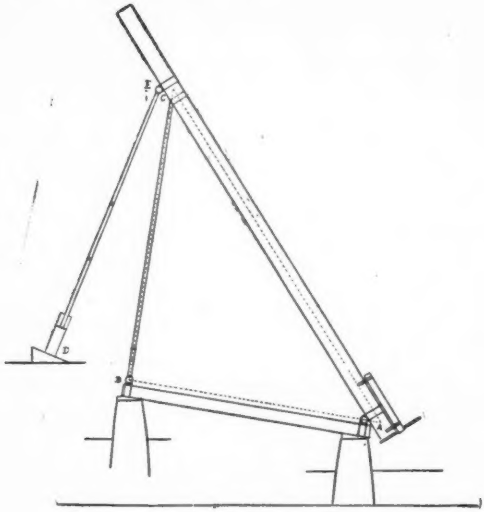


FIGURE 1.

The accompanying diagram presents the principle of the apparatus, and nearly explains itself. The essential geometrical idea involved in the equatorial telescope is that of a triangle, whose base is parallel to the axis of rotation of the earth, revolving about its base, the hypothenuse being elevated to the angular polar distance of the object. It is necessary then to support the sight line of the telescope at the proper angle, and provide for its rotation about the base fixed at elevation of the pole, and in the plane of the meridian. The dotted lines represent such a triangle.

The sight line, AC, is determined by the optical axis of the object glass; the base, AB, by the position of the axis of rotation; and the altitude BC by the value of the angle BAC, the polar distance of the Sun at the time of observation. The circles A,B,E, indicate a set of ball and socket joints, allowing free motion in any direction; C is a plane joint admitting motion only in the plane of the meridian. A and B are attached by clamp collars to a cylindrical iron tube, which rests upon cast iron forms holding the tube and anchor plates. For piers there were used a set of

oak iron-bound casks, filled with stone and cement, in which were embedded the anchor plates, suspended at some distance below the castings by four strong iron bolts. The contraction of the casks at the top, when once filled with the cemented material, kept the tops of the foundations in place, whenever subjected to strong lateral pressure, as was the case when the angle BCD had a considerable value. The use of casks in the field is recommended for these purposes; they serve in transportation, and permit the employment of loose stones and dirt mixed with cement in place of good brick or stone; they are much more quickly constructed and stand more wear and tear than any built up pillar piers; and they can be repacked for transportation, the only expense having been the cement.

Ball joints are needed at the points A,B,E, to preserve free motion of the sight line; they consist of solid iron spheres, which receive two sets of abutting screws at right angles. At C, the joint must be strong and constructed to prevent any rotation of the telescope about its axis of collimation, or else the position angles will need a correction. The thrust of the rod DE against the joint C effectually prevents such motion. We had the rod BC trussed with three rods running from end to end, elevated at the middle by three arms. The telescope was also supported against flexure by five such rods from A to C.

The rod BC, therefore, being stiff, could not introduce an error of rotation into the position angles, as the hour angle from the meridian increased. Near the lower part of this rod was introduced a heavy double threaded turn-buckle, by means of which, when once the length of the rod had been adjusted to produce the required angle BAC, small variations in this angle by way of adjustment could be produced. An assistant was stationed there, and by direction of the observer raised or lowered the telescope so as to bring the image of the Sun to any parallel of the photographic plate. The rod, DE, was built up of lengths, which could be rearranged for the altitudes occurring during the important phases of the eclipse, the required combination of parts being ascertained by a little computation, or by trial during the preparations for the observations. The parts were screwed together, and for this purpose it is convenient to have some bar wrenches adjusted to the size of the rod. The parts of the apparatus AB, BC, DE are hollow tubes, and ordinary two and four-inch gas pipes are strong enough for very large instruments, smaller diameters being sufficient for a twenty-foot tube. It will be observed that the method of support on the piers, by

which the ends of the tube are immediately secured, instead of suspending the telescope by the center as in the Fraunhofer mounting, reduces to a minimum any tendency to vibrations from the wind, and favors photographic operations in a marked degree. One of the motives in mounting a forty foot telescope direct, instead of parallel to the horizon, as was done in the case of observations on the transit of Venus, was to avoid all the questions arising in the use of the mirror, and at the same time secure rigidity, as was done in this disposition of weights on a tripod. The distances AB, BD and AD are so great, in respect to the size of the telescope, as to favor to the utmost stability of support.

The important problem to be solved was the imparting the requisite motion in hour angle about the axis AB, without the employment of a regular clock. A sand piston was substituted for it, and the success attending its trial gives us a valuable auxiliary for all such observations. The end of the rod ED terminates in a flat circular plate, which rests upon sand in a strong piston, the cap at the top guiding the rod, the flow from the piston being controlled by a valve invented for the purpose, set into the center of the bottom, and finally the whole piston resting upon a base that allowed it to move through any conical angle produced by the action of the rod ED. The use of sand for such a purpose has given trouble heretofore by the fact its flow is not steady under ordinary conditions. The tendency is to move by jumps; the sand congests and then flows spasmodically. This is due to two causes, first the presence of moisture in the sand, which gives a viscous sort of friction, and second to the shape of the orifice which generally has been circular.

The first difficulty was overcome by heating the sand thoroughly over the fire, before using it. The moisture once having been evaporated, the movement of the sand particles becomes perfectly uniform so far as friction is concerned. The sand was from the beach, washed free from dirt and carefully screened fine, so that the grains should be as nearly of the same size as possible.

The valve and form of the orifice which overcame the second obstacle to uniform flow was constructed as follows. The diagram represents in full size the valve that was used at Cape Ledo. A brass cylindar screws into the bottom of the sand piston; near the middle, on the inside, two conical ledges project a short distance towards the center; from the bottom, carried by a screw, a longer cone projects upwards, its axis coincident with the axis of the cylinder, and its sides parallel to the sides of the fixed cone,

as shown in the figure, which is a drawing of a section through the middle. By lowering or raising the cone, which can be done accurately, the passage through which the sand flows can be changed to any desired amount, up to the size of the opening between the fixed ring, or it can be closed entirely. The sand escapes through some holes into the cone which is hollow, and drops out at the bottom. It will be seen that the action of the cone is to pierce the flowing solid stream of sand at the center and convert it into a thin band in the form of an annulus. This stops the irregular action caused by congesting and freeing of the sand at a circular opening, and allows the flow to become steady and continuous. One other precaution should be taken with the sand piston, namely, the diameter must be large, about six inches, and the piston head must be free round about its edge by at least one-fourth of an inch. In this way the particles of sand work up between the piston head and the sides, forming an excellent friction surface, which works smoothly; and by having a large column of sand, there is no chance to congest under pressure as it falls away with the load. It was surprising to see how readily the sand piston carried a varying weight, ranging from 100 to 800 pounds, with apparently no impression upon the rate of speed as controlled by the valve. This speed was also sensitive to a half or even a sixteenth of a revolution of the cone, showing that the sand acts practically like a solid moving column. With this arrangement the Sun could be maintained tangent to the reticle threads for a considerable length of time. The pot used was about 2½ feet long and gave an effective flow to the forty-foot telescope for eighteen minutes, which was ample time to take all the pictures desired of any phase of the eclipse.

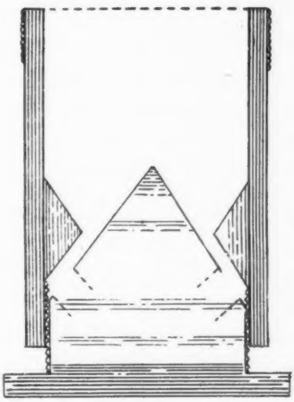


FIGURE 2.

Regarding the adjustment of the polar axis in altitude and azimuth, it is to be observed that the long rod of support, BC, lends itself to this purpose, by reason of the large triangle, ABC, of which it is a part. Calculating the angle BAC for any date, and the length of the rod corresponding, it is necessary simply, having made the end A fast, to set the telescope on the Sun at noon by raising the end B over the pier, and again on the same day

near the horizon for the azimuth. Or if preferred, by following the Sun during a given hour angle and observing the change in the length of the rod BC, as shown by the turns in the buckle, an easy computation will give the resolved part of this change in altitude and azimuth. For eclipse work, it would be hard to conceive a more expeditious way to set up accurately and firmly a large telescope than the one described. Instead of using sand, it might be, on some accounts, better to have an hydraulic piston and then by making the rod ED available at two points D and D′, one for raising and the other for lowering the telescope, it would be equally useful for forenoon and afternoon observations. At Cape Ledo the total eclipse occurred at 3 o'clock in the afternoon.

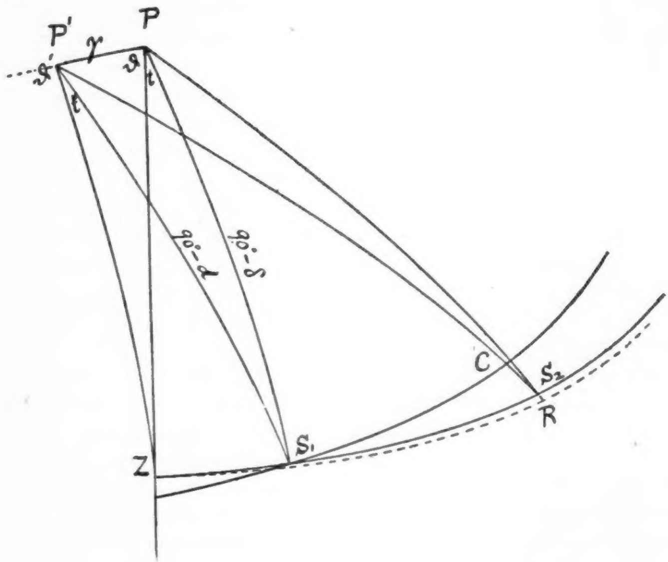


FIG. 3.

The instrumental corrections were easily obtained by the method which is indicated briefly at this time. In fig. 3 let P represent the true south celestial pole, P′ the instrumental pole, that is the intersection of the line AB with the celestial sphere, PZ the meridian, Z being the point at which the Sun crosses it; let S_1 represent the place of the Sun on its true path ZS_1S_2, at the hour angle t, or t' by the instrument; the dotted line ZR is the apparent path as modified by the action of refraction. Let ϑ, γ, be the co-ordinates of P′ as referred to P, $PS_1 = 90° - \delta$ the true po la

distance, and $P'S_1 = 90°—d$ the instrumental polar distance. The component of refraction resolved from the zenith altitude into the direction of the pole will give the point S_2 relatively to R at the time of an observation. Suppose at any time, t, the Sun is seen at S_1, then $90°—\delta$ is known from the Almanac, and $90° — d$ by computation from the triangle ABC. It is necessary once for all to measure accurately these linear distances, the great size of the triangle making it easy to secure the angles very exactly. At another time, t_2, the Sun appears at S_2, and the telescope is brought upon it by changing the length of the rod BC. This variation being found by counting the movement of the threads at the turn buckle. Hence by means of this variation and the linear distance AC, we compute the angular change CS_2. Now $S_1C = (t_2 — t_1) \cos \delta$, S_1CS_2 is a right spherical triangle, and the angle CS_1S_2 can be found, this being also the angle PS_1P'. Thus three parts of the triangle PS_1P' are known, and we obtain the required γ, ϑ, which can be readily changed into difference of altitude and azimuth of the instrumental pole. The linear dimensions of the triangle ABC and the variation of BC between two observations, are sufficient to determine the position of the instrument. The temperatures may be reduced to a standard temperature by introducing a coefficient of expansion for the tubes; it is best to take the two observations about three hours apart; a standardized steel tape, measuring the distances between proper marks on the tubes, the marks being referred to the inaccessible points, A, B, C, by suitable methods, will give us the linear dimensions at any time with great accuracy.

In the mounting of the telescope for eclipse observations, the objects aimed at were a minimum of expense and a maximum of stability; in the construction of the photographic apparatus it was attempted to secure invariable actinic conditions and rapidity of exposure during totality. We had an opportunity to test the same during the phases, but the totality was wholly obscured by clouds. The diagram (Fig. 1), shows the general position of the parts. A strongly built finding telescope is firmly attached to the main tube by ring struts, which carry abutting screws for adjustment. The axes of these telescopes are made parallel; the finder is used for viewing the region of the sky operated upon and for fixing the position of the camera. This consists of a large plate of plane glass, the surfaces being parallel planes, bound about by a thin brass ring, one-half an inch in width, one edge carrying a lip flange against which the plate is cemented with shellac. This plate is pierced at the center, re-

ceives and is screwed to a hollow axis with wide flange, this axis fitting and revolving upon the finder, so that the plate itself turns in front of the large telescope. In this way there is a wide annular surface of the plate that is available for photographic purposes in front of the field, successive circular surfaces being taken by turns, as the plate is moved from step to step. We used a 22-inch plate which gave ten 4½-inch circles without overlapping. The portion of the plate, on the side opposite to the objective, was spread over with radii and concentric circles ruled by a diamond, which referred any portion of this surface to coordinates whose origin is the axis of rotation. It is particularly to be observed that the focal plane, once secured by adjusting the finder in its bearings, is maintained constant throughout the observations, and that the surface of the plate, being perpendicular to the axis of the finder, is always also perpendicular to the optical axis of the objective, two conditions of great importance. Thus far we have described the essential features of the apparatus, the further process of manipulation depending upon the resources and the tastes of the observer.

Our photographic film was spread upon large circular plates, fitting inside the brass ring, the reticle lines and the film touching each other, so that there could be no parallax effect between them. Thus in one rotation of the plate ten independent pictures under identical conditions were secured, each image of the field available being 4½-inches in diameter. It was found practical to take a complete picture, once every six seconds, or the whole ten in one minute. If it is not thought best to use so large plates, it is evident that ten compartments can be constructed into which small plates can be inserted, and removed in regular order on the unemployed side, while the exposures are made on the other side of the plate. There is some trouble in making, handling and developing large plates, but in many respects, they are superior to a series of small plates, especially in referring them to the coordinates for measurements.

In conducting the exposures it is necessary to have two screens also revolving upon the axis of the finder, just in front of the plate between it and the open end of the tube, one to carry the slit and one opaque; each screen also revolving in one direction by the pressure of a spring. The order of action is (1) movement of the opaque screen, (2) passage of the slit screen for exposure, (3) return of the opaque screen in front of the tube, (4) return of the slit screen to place for a new exposure, and (5) the advance of plate through one-tenth of the revolution. We employed a rather

complicated automatic apparatus, acting by means of compressed air, which carried out all these motions automatically, so that the observer had only to exchange plates after each ten pictures, but a simple contrivance can be made to work by hand, that will do just as well and will not cost so much. The slit screen must be a sector covering rather more than twice the width of the tube, and the opaque screen more than once its width; they must strike against soft cotton batten for buffers, so as to impart no vibration to the telescope. It was found that the rigidity of the end A was such as to permit any necessary manipulation of the camera without disturbing the image of the Sun. At Cape Ledo the clouds were passing over the Sun so rapidly, when it could be seen at all, that it was not possible to use the automatic apparatus which had been planned, to execute prearranged intervals of exposure, by control from an electric dial invented for this purpose; and what we secured was obtained by watching the image on the opaque screen, as could be done perfectly from the side, there being a free space of about one half an inch, and letting fly the screens by hand, at any favorable instants of time. If one could practice with such apparatus I am sure that the pictures desired could be obtained with the least loss of time and under the most uniform conditions. It should be said that a small dark room was erected over the photographic end of the telescope so that all these operations went on under ruby light, being fully protected from causes that tend to ruin such delicate work. Black canton flannel secured over the large opening and around the telescope admits of all the freedom of motion needed by the instrument. Such a dark room can be constructed cheaply and quickly, and it seems to me that it is an indispensible part of an eclipse outfit.

There is one more problem that it is hoped was successfully attacked, namely the determination of the position angle. The position angle, or the position of the lines of reference of the plane of the ecliptic and the Sun's axis of rotation, is a question of extreme importance in the solution of the location of the coronal axes, along the lines of investigation described in other papers, and it is the weakest part of the work hitherto accomplished in taking coronal photographs. A picture of the corona, with such lines only roughly indicated, are not worthy the expense and labor otherwise bestowed upon them, and they miss one of the most important parts of this problem. All observers know the difficulty of securing this line of reference. What is needed is the direction of motion of the center of the Sun across the plate, as

the telescope rotates about its axis; or the telescope being fixed this direction as the Sun passes over the field. If the celestial and the instrumental poles PP', coincided on the sphere, these two directions would be the same.

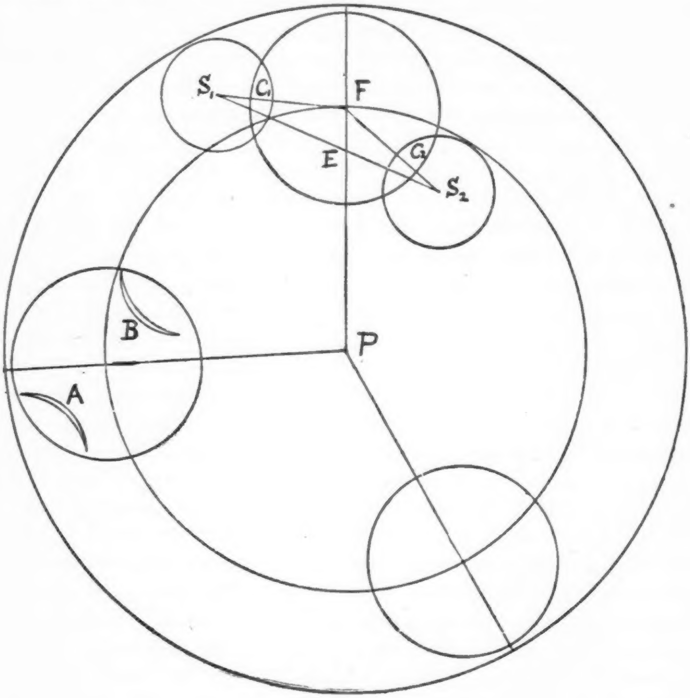


FIGURE 4.

Hence both of these lines should be determined, as a check and as a term in the problem of computation. In Fig. 4 let P represent the axis of rotation of the photographic plate, upon which are shown their circles and three radii belonging to the rotating reticle. Let F be the center of one of the fields from the objective, adjusted to coincide with the axis of collimation by means of a circular screen at the lower end of the instrument. This screen should also carry two threads at right angles, the center being adjusted to the optical axis of the telescope, and one thread parallel to the equator. S_1 and S_2 are the positions of the centers of the Sun at two exposures on the same field, the first after the cusp C_1 has entered and the second C_2 as the Sun is leaving the

field, the telescope being fixed and the Sun moving, or the telescope running past the Sun, by a rapid flow from the piston, as mentioned above. The general light of the sky is always sufficient to throw down the field with clearly defined edges. The points of the cusps C_1 and C_2 are sufficient to determine the directions FS_1 and FS_2 respectively, while the curvature of the edges of the Cusps serves to fix the positions S_1 and S_2. Hence the line S_1S_2 is the direction of motion of the Sun over the field, and the angle S_1EP refers this to the center of polar co-ordinates P. If now the thin cusp A, just before Contact II, and the thin Cusp B, just after contact III, are taken on the same field, one before and the other after totality, it is obvious that we should have room for nine pictures of the corona on the same plate, giving time for some long exposures if desired. The curves of the edges of the Sun and the moon can respectively be extended to the circumference of the field, and thus the direction of the motion of each of these bodies be accurately obtained. It is felt to be very unfortunate that our ill luck at Cape Ledo prevented us from carrying out these plans fully. A number of plates (10) of phases were obtained, which show all the mathematical lines that have here been indicated, but they are not as yet measured up and computed.

There is space remaining for only three isolated remarks. The first is that the evidence is very strong, as shown in a paper on "Standardizing Photographic Films," which appeared in the SIDEREAL MESSENGER of Nov. 1891, that in the present state of our knowledge regarding the actinic problems of photographic films, it is quite useless to repeat the process of standardizing the films by squares, and comparing with the effects of deposit produced under exposure to the corona. The second is that it is highly important to develop the plates as soon as possible after the exposure, if it is expected to retain all the impression produced. There are now several experiences on record that show that the images do fade out with the lapse of time. Some of our plates were developed at San Paulo de Loando in a few days after the eclipse, and others in the United States after the return of the expedition. The latter had all faded away seriously as compared with the Loando plates, and there were no precautions spared to prevent this result. In spite of the practical difficulty of developing plates in hot climates, and with insufficient means, it is better to do so, and if the work is done at night in a cool place, the best will have been done that is possible. The third remark is that from a careful study of the corona pictures

available, I find that those produced by the old colodion process, such, for example, as that used by U. S. Naval Observatory parties in 1878, gives a better working picture than any of the gelatine dry plates. They are more homogeneous, the lines being much more continuous in their courses under the microscope, and they preserve this continuity much better from near the edge of the Sun where the object is bright, towards the extremities of the streamers where the corona disappears in the general brightness of the sky. There is time enough for sufficiently long exposures to use colodion, since it is a mistake to expose a quick gelatine film (Seed No. 27) for more than about three seconds.

There are many other processes that were undertaken by the expedition, especially in the way of automatic exposures, as conducted by Professor Todd himself, which show that the old method of hand manipulation ought to be abandoned, in view of the value of the available minutes. Of course nothing can take the place of a good observer, but wherever it is proposed to supplement such observations with photographic records, there can be no doubt that the introduction of mechanical operations has been a step in the right direction.

NOTE ON THE NEW BINARY, β 612.*

S. W. BURNHAM.

In THE SIDEREAL MESSENGER for August, 1891, I called attention to the rapid motion of this new system, and gave all the measures I had any knowledge of at that time. With these observations, owing to the uncertainty of the quadrant, it was impossible to say whether the motion was direct or retrograde, since the components are very nearly equal, and the several positions might lie in the same quadrant. The direction of the motion seemed to depend upon the general accuracy of Engelmann's angle in 1884, and that made the orbital motion in a retrograde direction.

Since that paper was written, I have received some very valuable unpublished measures from Schiaparelli, made in 1889, 1890 and 1891, and from Hall in 1891; and in addition to these observations, I have recently measured it with the 36-inch equa-

* Communicated by the author.

torial. These observations show beyond question that the motion is direct, and that the angular motion since 1878 is about 140°. There seems to be a large error in the position-angle of 1884, which it is difficult to explain. The period will be short, and with the measures of the next two or three years, it can probably be determined with approximate accuracy. At the present rate, with a uniform motion of 10° per year, the period would be only 36 years, but it is not at all unlikely that the angular motion may be accelerated during the remainder of the apparent orbit.

HISTORY OF THE COLOR OF SIRIUS.*

T. J. J. SEE, BERLIN.

In the *Philosophical Transactions* for 1760 Mr. Thos. Barker of Lyndon, in Rutland, has a paper "On the Mutations of Stars," in which he calls attention to a supposed change in the color of Sirius, and cites as a proof that the star was formerly red the testimony of a number of ancient authors, including Aratus, Cicero, Horace, Seneca and Ptolemy. The argument advanced seemed so conclusive that for a long time the change of color appears to have been accepted as an item of scientific belief. Recently, however, an effort has been made to discredit belief in the ancient redness of Sirius by throwing doubt upon some of the evidence cited by Mr. Barker, especially the weighty testimony of Ptolemy, Seneca, and Cicero. Therefore, to satisfy my own curiosity, I undertook a critical investigation of all of the ancient authors hitherto examined, and a great many others, with a view of deciding definitely whether in antiquity Sirius was really red. The results of the research seem to establish beyond doubt the ancient redness of the star, and therefore, since the investigation will be interesting to astronomers who are studying problems of Cosmical Physics, I shall now proceed to give briefly the evidence of the ancient authors and to review in the proper place the criticisms hitherto advanced, nearly all of which happen to be erroneous. We shall proceed usually in chronological order.

HOMER.

The only distinct allusion to Sirius in the Homeric poems is that in the Iliad (Bk. XXII, 29-32,) where Homer compares

* Communicated by the author.

Achilles' shield (of copper, as we know from recent Archælogical discoveries) to the star:

> "*ὅν τε κύν' Ὠρίωνος ἐπίκλησιν καλέουσιν·*
> *λαμπρότατος μὲν ὅ γ' ἐστὶ, κακὸν δέ τε σῆμα τέτυκται*
> *καί τε φέρει πολλὸν πυρετὸν δειλοῖσι βροτοῖσιν*
> *ὣς τοῦ ταλκὸς ἔλαμπε περὶ στήθεσσι θέοντος.*"

We have here no distinct record of color, but the association of "*πυρετός*," meaning "fever" (the same word is used by Hippocrates), with Sirius, indicates that there must have been some reason for ascribing the presence of a disease which the Greeks evidently connected with "fire" or "heat" to Sirius rather than to other stars. The evil omens attributed to Sirius were perhaps the natural outcome of astrological superstitions widely spread in antiquity respecting the "influences" of bodies of a ruddy color, which were looked upon as "angry" deities. It is well known that Mars (the god of war) and the sign of Scorpion (owing without doubt to the "angry" appearance of the ruddy Antares) were objects to which astrologers attributed all manner of evil. It is also well known that the "influences" of clear bright bodies like Venus and Jupiter were considered "salutary;" therefore it is difficult to imagine why the ancients should have attributed evil omens to Sirius if it shone with its present "salutary" appearance. But certain it is, as we shall see in the course of this paper, that throughout the Greek and Roman world the Dog Star was regarded as the cause of the intense heat of the "Dog Days," as the source of the sickness and droughts attending that season of the year, and consequently an object of the greatest superstitious terror. It is easy to see how these evil forebodings would arise in the minds of the ancients if Sirius were red, so as to present the appearance of "burning," but if the star were white (clear and "salutary") an explanation of these superstitions seems nearly impossible.

Homer, moreover, by comparing the shining of a copper shield to the "Dog of Orion" has used language consistent with the idea that Sirius shone with a ruddy light, and it may be that he has thus unconsciously preserved for us the color of the star 3000 years ago. This suggestion is confirmed by the following comparison of the helmet and shield of Diomede to the "Autumn Star," which critics are agreed is Sirius:

> "*δαῖέ οἱ ἐκ κόρυθός τε καὶ ἀσπίδος ἀκάματον πῦρ,*
> *ἀστέρ' ὀπωρινῷ ἐναλίγκιον, ὅς τε μάλιστα*
> *λαμπρὸν ὀπαμφαίνῃσι λελουμένος Ὠκεανοῖο·*

τοῖόν οἱ πῦρ δαῖεν ἀπὸ κρατός τε καὶ ὤμων,
ὦρσε δέ μιν κατὰ μέσσον, ὅθι πλεῖστοι κλονέοντο."

(Iliad, Bk. V. 4-8).

Homer therefore affirms the similarity in the appearance of the "imperishable fire;" streaming from Diomede's copper armor to that coming from the "Autumn Star;" and the repetition of "πῦρ" not only emphasizes the agreement in color, but assures us that the objects were fiery red. Now Homer's similes and comparisons are admitted by all critics to be in general proverbially accurate; therefore it is very improbable that he has here committed so great an error as would be implied by the same comparison at the present day—a comparison, indeed, very appropriate for a red star like Aldebaran or Betelgeux or Antares, but entirely inadmissible for the bluish white Sirius with which we are all familiar. It must be remembered also that the Greeks of the Homeric age knew nothing of the white lights and fires resulting from oil, gas, and electricity, but that their primitive wood fires presented a ruddy tinge. In remarking that the star "appears more brilliant when washed by the ocean." Homer has left us a record of scintillation—certainly the very earliest that exists—but his language does not imply that his judgment of the color has been influenced by atmospheric effects upon the light of the star. Scintillation, indeed, causes the flashes of a red star like Aldebaran to appear extraordinarily red, and the flashes of a bluish white star like the present Sirius to appear extraordinarily blue; therefore in the present color of Sirius not even scintillation could justify the comparison with "imperishable fire" or the ruddy glow of burnished copper; whereas, with a color like that of Antares such a comparison would not only be admissible but the most natural that could be imagined, whether scintillation existed or not. Accordingly, although the two foregoing independent and very ancient records of Sirius have come down to us from a poet, Homer is generally very accurate in his descriptions, and therefore his testimony ought to lay claim to considerable confidence.

HESIOD.

The name *Σείριος* first appears in Hesiod ["Works and Days" (415, 585, 607) which probably dates from the 8th century B. C.,] and seems to mean the "burning one." For *Σείριος* is evidently intimately connected with the verb *Σειρέω* (otherwise *Σειρόω*, or *Σειραίνω*) which means to "burn," "consume," "dry up" or "sear." Hesiod says:

"ἐπεὶ κεφαλὴν καὶ γούνατα Σείριος ἄζει."

A general name for Mars among the ancients was πυρόεις, the "fiery one," which shows that the color of this planet was carefully noted. If "Σείριος," as we have suggested, means the "burning one," the meaning in the two cases is essentially the same. Antares seems to be redder than even Mars, and hence it has been suggested that the name of the star is derived from ἀντι-Ἄρης, the "rival of Mars." The linguistic evidence certainly favors the idea that these three bodies were formerly of the same color.

EURIPIDES.

The language of poets is always very uncertain, but one passage in Euripides is given for what it is worth:

"Σείριος ἔνθα πυρὸς φλογέας ἀφίησιν ὄσσων αὐγάς."

(Hecuba, 1080)

APPOLLONIUS RHODIUS.

This writer has the following remark on Sirius:

"Ἦμος δ' οὐρανόθεν Μινωΐδας ἔφλεγε νήσους Σείριος."

(2, 517).

ARATUS.

In verse 329 of the "Phenomena" Sirius is called ποικίλος, which is susceptible of several translations. The most usual is "highly colored," or "various colored," either of which can be justified by classic authority. For example, there was a gate at Athens called Ἡ ποικίλη (with or without στοά) from the circumstance that Hyron had adorned it with paintings in bright colors (red, blue and green). Now, since Aratus uses words in their correct sense, and does not use ποικίλος of any other star, it is to be presumed that the appearance of Sirius was something extraordinary; and in the present case about the only meaning that can with any probability be assigned to ποικίλος is "ruddy."

In 331-2 Aratus continues:

"ὅς ῥα μάλιστα
ὀξέα σειριάει· καί μιν καλέουσ' ἄνθρωποι
Σείριον;"

This remark confirms the derivation of the name Sirius just given in speaking of Hesiod, and shows clearly that Σείριος means the "burning one."*

It may be added that there is an extant commentary on Aratus by the great astronomer Hipparchus, who points out many

* The derivation of Σείριος given by Ideler in his "Sternnamen" is certainly erroneous.

errors in the celestial geography of his author, but makes no comment on ποικίλος. Considering the scrupulous care which characterized all of Hipparchus' work, it would seem that he must have considered ποικίλος a correct description of Sirius.

Using Buhle's edition of Aratus (Leipsic, 1796) we shall now consider the Roman translations.

(1). THE TRANSLATION BY CICERO.

This appears to be in general a fairly faithful rendering of the original. In verses 326-7 we read:—

"Namque pedes subter rutilo cum lumine claret
"Fervidus ille Canis, stellarum luce refulgens."

The word ποικίλος is thus rendered "rutilo cum lumine," apparently because the word had that meaning, or because Cicero knew from observation that Sirius shone "with a ruddy light." In the whole of his writings, as I have found by careful investigation, Cicero does not use the word "rutilus" (or any other word meaning red) in speaking of any other heavenly body except the planet Mars, which in the Somnium Scipionis (Cap. IV.) is styled "rutilus terribilisque terris." No foreigner ever understood Greek better than Cicero, and therefore he can not have been ignorant of the meaning of his text, nor is there the slightest ground for saying that he was a "rhetorician rather than a natural philosopher," as one critic has asserted. For it is a matter of universal knowledge that Cicero devoted great attention to the Greek philosophy, consecrated, as it was, in so large a degree, to theories of the system of the world; it is therefore certain that he was perfectly familiar with the appearance of all the conspicuous heavenly bodies, and especially of so famous and prominent a body as Sirius. Considering the out-door life of the Romans, we can not doubt that Cicero had observed the Dog Star hundreds of times; hence when he wrote "rutilo cum lumine" he recorded the color with which he had long been made familiar.

(2). THE TRANSLATION BY GERMANICUS CÆSAR.

The fairly good translation left us by this Roman general singularly contains no rendering of the Aratus' ποικίλος, probably because the word was accidentally overlooked. However, in the same passage as ποικίλος, but 12 verses further on, Germanicus distinctly implies the redness of Sirius:—

"Urgetur cursu rutili Canis ille per æthram"
(verse 341).

"Cursu rutili" may therefore be taken as the equivalent of ποικίλος. Germanicus' use of words throughout the translation is classic, and I have found by careful examination that "rutilus" is used of no other star, not even Antares, which he evidently alluded to when he speaks of the Scorpion as "ardenti cum pectore" (653). Therefore, since it is certain that Germanicus was familiar with the appearance of the conspicuous heavenly bodies, his testimony for the redness of Sirius ought not lightly to be set aside.

(3). THE PARAPHRASE BY LUCIUS FESTUS AVIENUS.

This author is supposed to have flourished towards the end of the 4th century A. D. His translation is only a very rough paraphrase of the original, and the words are very loosely used. Therefore but little importance can be attached to what he says in speaking of the Dog:—

"Multus rubor imbuit ora."

(verse 727).

THEON.

This Alexandrian mathematician wrote a commentary on Aratus about the end of the 4th century A. D., and in explaining ποικίλος says the light of certain stars is "not composed of one ray, but various colors," (Buhle's Aratus, vol. I., p. 291). Theon thus says that Sirius is ποικίλος, but his use of words does not seem very classic. An unknown scholiast has explained ποικίλος as equivalent to "πορφυρίζος" (Buhle's Aratus vol. I., p. 83) which can be translated "purple," but here perhaps the rendering should be "ruddy."

[TO BE CONTINUED.]

A FURTHER NOTE ON COMETS AND METEORS.*

W. H. S. MONCK.

Besides the four meteor-showers which are usually regarded as cometary, Professor A. S. Herschel communicated a long list of supposed accordances to the Royal Astronomical Society in the year 1876, which was included in the report of the Council for that year; and in the *Monthly Notices* for 1878 appeared a further development of this list also by Professor Herschel. No correction of these lists has, so far as I am aware, hitherto ap

* Communicated by the author.

peared, and the Royal Astronomical Society decided on not publishing a criticism by the present writer, I presume because the list had received the *imprimatur* of the Council. It may not, therefore, be amiss to show briefly that the great majority of these accordances are purely imaginary and have not been borne out by subsequent observation, and especially that they are not to be found in the great catalogue of Mr. Denning, published in the *Monthly Notices* for May, 1890—a catalogue containing the results of some twenty years of accurate observation by a most pains-taking observer.

Professor Herschel's idea of what constitutes an accordance differs widely from mine. Take, for instance, the very first comet in his list, the second comet of 1792. Meteors attached to this comet would have (according to Weisse) a radiant at $194° + 24°.5$, the date being January 5th. The supposed accordance is with these meteor-radiants, one at $183° + 28°$ from Schiaparelli and Tezioli on January 11-12, and the others at $180° + 35°$ and $183° + 36°$ respectively, extending through the greater part of January, one resting on the authority of Colonel Tupman, and the other of Grey and Herschel. The two latter evidently represent the same radiant, but the accordance does not approach within 10° either in right ascension or in declination, and the shower lasts for at least three weeks after the earth has passed the cometary node, the inclination being 49°. Schiaparelli and Tezioli's radiant approaches nearer in declination, but its right ascension is wrong by over 10° and the date erroneous to the extent of a week. If we allow ourselves this amount of latitude there is probably not an observed meteor-radiant for which we could not find a comet, or a cometary radiant for which we could not find an observed meteor-shower. For as both meteor-radiants and (theoretical) cometary radiants are reckoned by the hundred and are distributed over all parts of the sky, such accordances must take place; but I believe equally good accordances could be obtained for points and dates selected at random, provided that the selected portion of the sky was suited for meteor-observation at the time. In this instance Mr. Denning's observations confirm the discordance. His nearest shower is from $180° + 24°$ on the 25th of January and the column "*Other nights of observation*" is a blank. Mr. Denning did not observe any meteors from the cometary radiant and I am not aware of any one who did.

The table itself is indeed sufficient to show the hap-hazard manner in which its results have been arrived at. Two supposed coincidences are introduced into the table in deference to Weiss

and Schiaparelli respectively (see Report of the Council for 1876), though the great distance of the earth from the comet's orbit renders Professor Herschel very doubtful as to the connexion; but the coincidences are quite as good as in the majority of other cases. Professor Herschel, in computing the radiant for the first comet of 1870, made a serious arithmetical error, the result being that an excellent coincidence was detected; but on the error being corrected, a new coincidence, not quite as good as the former one, immediately came to light. And no doubt if a second correction had become necessary, a third coincidence would have been discovered; for the whole region of Perseus and Andromeda swarms with meteor-radiants about the 12th of August when the earth reaches the node of this comet's orbit. I may take another example from the early part of Professor Herschel's table—the fourth in his list. The comet of 1746 gives a radiant at $60° + 40°$ with the date January 16. The nearest of Professor Herschel's supposed agreements is wrong by 15° in declination. Mr. Denning discovered one of his stationary or long-enduring radiants near this point, but it so happens that one of the months during which the shower appears to be quiescent is the month of January.

The table as such is, I think, worthless, but it may be worth inquiring whether any of the radiants comprised in it are borne out by Mr. Denning's and other recent observations. The examples of this kind are perhaps not more numerous than chance will account for, but they seem worth giving in detail in order that further investigation may lead to some definite conclusions with regard to them.

1. Comet III 1759 has a radiant at $210° - 15°$,* date January 19. On January 22 ("other days of observation" January 19, 20, 25), Mr. Denning observed a radiant at $210° - 8°$. The difference in declination is considerable but the shower is worth watching. There are, however, some indications of a stationary radiant near this point, Mr. Denning having observed meteors from it in February and April which could not be ascribed to this comet.

2. Comet 961 is assigned a radiant at $308° + 12°$ for March 23, and Comet 1857 V a radiant at $302° + 11°$ for April 4. Mr. Denning deduced from Italian observations a radiant at $304° + 12°$ for the period March 31 to April 12, and observed a

* Professor Herschel's radiants seem to have been arrived at by a graphical construction and are probably not very accurate. Mr. Corrigan or Mr. Winlock might find the table worth going over from this point of view.

radiant at $303° + 13°$ on April 19. As there are no radiants for the early part of April in his catalogue an earlier display of this shower may have escaped his notice. The shower agrees better with the comet of 1857 than with that of 961. This comet is an elliptic comet. There are some indications of a stationary radiant near the point.

[One of the next agreements in Professor Herschel's table is between the Comet I 1847, whose distance is very considerable at the node, and a meteor-shower in April from nearly the same point. The date of the cometary shower, however, is April 11, while Mr. Denning's observations of the meteor-shower extend from May 7 to May 18. The identity in this case may therefore be rejected though the agreement in position is very good. For similar reasons the comet of 1746 (radiant at $296° + 1°.5$ on March 26) cannot be connected with a stationary radiant observed near the same point by Mr. Denning, the nearest agreement in date being April 15th.]

3. Comet II 1844, radiant at $288°.5 + 5°$ on April 21st. Mr. Denning observed meteors from $286° + 5°$ on April 19 and the point does not seem to be a stationary radiant. The comet is supposed to be elliptic.

4. Comet I 1737 gives a radiant at $235° - 15°$ for May 8. Mr. Denning observed meteors from this radiant on April 16-21. The accordance is very doubtful.

5. Halley's comet gives a radiant at $337° + 0°$ for May 4. Mr. Denning observed meteors from $337° - 2°$ from April 30 to May 6.

6. Comet I 1781 gives a radiant at $338° + 57°$ for June 14. Mr. Denning observed meteors from $335° + 57°$ from the 10th to the 28th of June; but among the stationary or long-enduring radiants enumerated by him is one at $334° + 58°$ which continues active from July to January. This throws considerable doubt on the connexion between the comet and the meteors.

7. Comet I 1850 gives a radiant at $312°.5 + 60°.5$ for June 20. More than one of Mr. Denning's radiants are in fair agreement with this; but the question, as in the last instance, is complicated by the existence of a stationary radiant, and the nearest agreement in date is one of the worst as regards position. It is at $302° + 64°$ on June 14 and 17. On June 13 meteors were traced to $310° + 61°$, and on July 1 to 6, to $313° + 60°$, a point which was also active on June 4. Meteors from pretty near the same point were observed in August, September and October. Schiaparelli's date is July 10 and Mr. Denning obtained the same

result from Italian observations July 15 to August 2. The comet is believed to be elliptic.

8. Another doubtful accordance is between Comet IV 1822, radiant 348°.5 + 28° on June 25 and a shower from 344° + 27° observed by Mr. Denning on July 7. This comet is also elliptic. There appears to be a shower of some duration from about 333° + 27° of which Mr. Denning's radiant on July 7 may be an outlier.

9. Equally doubtful is the accordance of Comet 1764 (radiant at 49° + 45°.5 on July 25) with several radiants observed by Mr. Denning. One of the best established stationary radiants on his list, which is active from July to January, is situated at about 47° + 44°. Its position for the 25th of July appears to be at 48° + 43°.

10. The comet II 1877 has a radiant at 32° — 18°.5 on August 9. On July 28th, 1878, Mr. Denning met with a shower from 33° — 20°. The comet is supposed to be elliptic.

11. Comet II 1780 has a radiant at 3°.5 + 38°.5 for August 14. Radiants in tolerable agreement may be found in Mr. Denning's Catalogue, but there is a well-established stationary radiant, active from June to October, whose mean position is given by Mr. Denning at 7° + 35°. The declination of the observed radiants seems to be always less than that of the cometary radiant, while the R. A. is usually greater.

12. Donati's Comet of 1858 has a radiant at 100° + 59° for September 8. Mr. Denning observed meteors from 100° + 58° on September 5 and 7. The comet is elliptic. There are, however, some indications of a stationary radiant. Mr. Denning obtained 100° + 60° from Italian observations October 29 to November 13 and Schiaparelli 100° + 59° for December 9. Mr. Sawyer obtained meteors exactly corresponding with the cometary radiant.

13. Comet 1769 gives a radiant of 21°.5 + 17°.5 for September 28, this being of the kind which Professor Herschel calls an appulse. Mr. Denning observed radiants at 20° + 14° on September 19, 23° + 17° on October 5-7, and 21° + 14° on October 13-19. The agreement is not very good but is suggestive of further inquiry. The comet is believed to be elliptic.

14. Comet VI 1847 has a radiant at 54° + 52°.5 for October 4. Mr. Denning obtained meteors from 56° + 52° on October 5-8. The point however, lies very near to the permanent Perseid radiant and in particular to Col. Tupman's radiant for September 7 to 15.

15. Comet II 1825 has a radiant at $134° + 77°$ for October 7. Mr. Denning observed meteors from $133° + 79°$ on that day; but there seems to be a stationary radiant at this point, as he obtained meteors from $134° + 78°$ in July, from $135° + 78°$ in August and from $136° + 77°$ in November and December. The last observation was confirmed by Italian observations which gave a radiant at $140° + 77°$ in January. This stationary radiant seems to be distinct from another which is situated about 10° farther S.

16. Comet II 1850 has a radiant at $2° + 54°$ for October 19. Mr. Denning traced meteors to $7° + 51°$ on October 15, 19 and 20. Besides the difference of some degrees in position there seems to be a stationary radiant near $7° + 51°$ which is most active in July and appears also in August and November.

17. Comet II 1842 has a radiant at $81° + 57°$ for October 21, and Comet I 1848 at $78° + 60°$ for October 25. Mr. Denning observed a radiant at $78° + 57°$ on October 14-15; but one of the stationary radiants in his list at $77° + 56\frac{1}{2}°$ lasting from September (he might, I believe, have said August) to November.

18 and 19. There is a somewhat similar agreement between the Comet of 1739, radiant at $157° + 39°$ on Oct. 22, and Mr. Denning's stationary radiant at $154° + 40\frac{1}{2}°$, September to December; and also between Comet 1582, radiant at $89° + 36°$ on Nov. 9, and a number of radiants situated at about $87° + 34°$ observed by Mr. Denning from September to December. The orbit of the latter comet is very uncertain and no reliance could, in any event, be placed on the apparent coincidence.

(As a specimen of Professor Herschel's powers of identification, I may mention that he connects both the Orionids of October and the later Taurids at the end of November with the Comet of 1821, radiant at $86° + 19°.5$ on November 11. No one would, I presume, now identify the two showers or connect the comet with either.)

20. Comet I 1813 has a radiant at $147° + 0°$ for Nov. 24. Mr. Denning observed meteors from $148° + 2°$ on Nov. 25–28. These meteors, however, are probably connected with others from $145° + 7°$ in December and $146° + 4°$ in January. Mr. Denning recognizes a stationary radiant at $145° + 7°$, Nov. 26 to Feb. 27.

21. Comet VII 1846 has a radiant at $200°.5 + 4°.5$ for Dec. 12-17. Mr. Denning has a radiant at $201° + 4°$ for Dec. 21-28. There seems to be no stationary radiant here. The comet is elliptic.

22. The great Comet of 1680 has a radiant at 132° + 21°.5 for December 26. Mr. Denning observed meteors from 129° + 19° on Dec. 21, 22 and 24. The comet is elliptic.

If we add to the foregoing list the four comets usually referred to and Comet I 1870, the corrected radiant of which agrees pretty fairly with a shower from Andromeda which occurs simultaneously with the Perseids, the list will, I think, be found nearly complete. The weight which should be attached to the agreements is a different matter. According to a theory still current, according to which a comet is, in fact, a swarm of meteors, the weight seems to me to be very small in most cases. If, for instance, the cometary theory supposed such a rapid shifting in the radiant as Mr. Denning is supposed to have observed in the case of the Perseids, the mere difference in date would often convert a supposed accordance into a discordance. Thus an advance of 1° *per diem* in the R. A. of the radiant would give a difference of 16° instead of 4° in R. A. in the case of No. 8. But if, as I have previously maintained, the chief effect of a cometary node is to render all stationary radiants in that part of the sky more active, a connection of this kind may perhaps be traced in several cases.

In some instances, however, the stationary radiant seems to be unusually quiescent at the time that we reach the comet's node. The best coincidences in the list occur with elliptic comets. Those with the comets of Halley and Donati and Comets II 1844, and VII 1846, must be regarded as very close. The result with regard to the great comet of 1680 is peculiar. Two observations made in different years give exactly the same deviation from the cometary radiant, and the effect of this deviation (according to the orbits computed by Dr. Kleiber) is that the meteors, instead of grazing the Sun, will fall into it—some of them almost centrally. With regard to these computed orbits I may remark that in almost every case in which an apparent coincidence occurs the perihelion distance of the meteors is greater than that of the comet (the comet of 1680 is of course an exception), as if the meteor-train was dragged on after the comet and never approached the Sun as closely as the comet's nucleus.

The orbits computed by Dr. Kleiber for Mr. Denning's radiants do not exhibit that preference for high inclinations which Professor Newton regards as evidence of an origin beyond the limits of the solar system in the case of the comets. The connection between the two is therefore perhaps acquired rather than original, and elliptic comets which remain for ages moving within the limits of the solar system display this acquired connection most clearly.

SOPHIE KOWALEVSKI.*

CHARLOTTE C. BARNUM.

Mme. Sophie Kowalevski (or Sonja Kovalevsky) was born in Moscow, Dec. $\frac{15}{27}$, 1853. Her father, Gen. Corvin-Krukowsky, was a man of marked ability and a member of the old aristocracy, being a direct descendant of Mattias Corvin, king of Hungary. Her mother belonged to the Schubert family of mathematicians and astronomers, and was herself an unusually gifted woman. Sophie's father retired from active service while she was very young, and took up his abode at his ancestral castle at Palibino, a lonely spot which, at certain seasons, was entirely cut off from the outside world. She began her studies under an English governess. A little anecdote of her childhood has found a place in several learned journals, but the moral is slightly obscure. When she was ten years old, the castle was re-papered, but when the paper came from St. Petersburg, it was found that there was none for the nursery. For this room was used a lithographed course of Ostrogradski on mathematical analysis, a survival of her father's student days; and, to the despair of her governess, she was continually reading these mathematical dissertations covered with incomprehensible hieroglyphs. When, at the age of sixteen, she began to study calculus, her professor was astonished at the quickness with which she understood him, "just as if it were a reminiscence of something you knew before," he told her. The continual reading of the wall-paper had left some unconscious traces on the child's mind.

From eight to fifteen years of age, her tutor was Mr. J. Malevitsch a fine teacher who, under the wise supervision of her mother, devoted himself with zeal and success to her education, and exerted a marked influence on the rapid development of her brilliant powers. Her literary ability was so marked that her tutor predicted for her a brilliant future as a writer, and he was not mistaken in his estimate of her powers in this line. Her *Reminiscences of Childhood*, translated into Swedish and Danish under the title, *The Rajewsky Sisters*, is spoken of in *Nature* as "one of the finest productions of modern Russian literature," and its publication was welcomed in Russia, Sweden, and Denmark as an event in literature, and it was said a new Tolstoi had been born in Russia.

* Read before the Mathematical Seminary of Johns Hopkins University, Jan. 6, 1892.

Her special interest in mathematics was awakened by her uncle Schubert, and she chose that specialty in her fourteenth year. She had studied by herself a text-book on physics, found among her father's books. The author, a friend of her father's, was once visiting him at Palibino, when Sophie told him she had studied his book. He laughed and said it was impossible, as she did not know trigonometry. But it appeared in course of the conversation that the girl, from the knowledge she then possessed, had deduced in her own way the fundamental formulæ of trigonometry. Astonished at so remarkable a proof of her intellect, the visitor urged her father to have her talent cultivated in spite of the aristocratic and conservative view of the education suitable for a lady of high rank. Her father thinking her passion for the study was only a caprice, readily consented, and she was allowed to study a year at St. Petersburg. But when, at the age of fifteen, she seriously asked permission to study in a foreign university, there was a terrible scene in the family. Her father could not have taken it more to heart if she had committed a grave fault.

In order to understand what follows, it is necessary to remember that at that time in Russia a girl who studied was considered a nihilist. There was indeed a political and patriotic enthusiasm in the burning desire for study which had seized the rising generation. It was a wish to impel their beloved country towards the light of liberty. This enthusiasm had produced a curious phenomenon,—marriages contracted for the purpose of freeing the girl from her father's authority and giving her the chance to study abroad. For this reason Sophie Korvin-Krukowsky, at the age of fifteen, married Vladimir Kowalevski, legally, but with the understanding that both should be free to devote several years to study. With her husband, her sister, and a friend, she went to Germany, and he entered one university, while the three girls went to the only German university open to women,—that at Heidelberg. The University of Berlin was so tightly closed that when, a few years later, she was a professor at Stockholm, and wished to attend a course of lectures at Berlin, she was refused permission, and finally obtained admittance only by the direct intervention of the Minister of Education as a great personal favor.*

After a year at Heidelberg she went in the autumn of 1870 to

* An American girl, Miss Ruth Gentry, the holder of the European fellowship of the Association of Collegiate Alumnæ, is, however, now attending mathematical lectures at the University of Berlin, where she says she is shown "all the courtesy and kindly consideration" she could wish.

Berlin, and timidly asked Weierstrass for private lessons, as she could not be admitted to his lectures. He thought at first that the girl would become only a *dilettante* in science, and he did not wish to waste time teaching her. But during the conversation he discovered in her such wealth of ideas, and so remarkable an intuitive grasp of the more difficult questions of the science that it became a pleasure for the great mathematician to instruct her. Four years she spent as his private pupil, her studies being interrupted only by a visit to her family in Russia and by some other trips. Being unable to obtain a degree at Berlin, she took the oral examinations at the University of Göttingen, presented a remarkably original thesis "On the Theory of Partial Differential Equations," and obtained the degree of Ph. D., being the second woman to receive this degree at Göttingen.

Her husband received his degree at the same time, and was appointed Professor of Paleontology in the University of Moscow, where he soon attained a position of distinction among the Paleontologists of the world. She was twenty-one when they returned to Russia, and established their home in Moscow. With her enthusiastic temperament, she devoted herself completely to whatever work she undertook. At first her home duties absorbed nearly all her time and thought. Then she took up her husband's specialty with such success that for some time, while he was otherwise occupied, she wrote his lectures for him. Then, being in a literary atmosphere, her taste for literature revived, and she wrote a novel entitled *The Private Teacher*, dealing with University life in Germany, and published it anonymously in a Russian journal. Thus passed several years of rare domestic happiness in their beautiful home in Moscow.

Professor Kowalevski was full of grand ideas and of enthusiasm, but exceedingly visionary. He fell under the influence of an adventurer, who drew him into dangerous speculations in petroleum wells and other industrial enterprises. She used all her efforts to break the spell of this false friend, but the fever of speculation was too strong, and he risked all his inheritance and his wife's and lost. Although he had committed no crime, he felt the disgrace so keenly that he left his home and position to resume his solitary studies abroad. Probably his mind had become unbalanced by their financial ruin. Soon came the startling news that in a fit of despair he had committed suicide. Thus the burden which had proved too heavy for him fell upon her alone, together with this great additional sorrow. Her parents were dead, her wealth had been thrown away, and as soon as she recovered

a little from the shock of the tragedy she found herself for the first time forced to consider the question of money. She must support herself and her four-year-old daughter. In Russia the best she could do was to teach arithmetic to one of the lower classes in a girl's school. Then came in the autumn of 1883 a signal illustration of the liberal spirit and kindness which mathematicians and astronomers almost invariably show to the women working in their departments. Mittag-Leffler, who had also been a pupil of Weierstrass, was at this time organizing the University of Stockholm, and, although she had published no mathematical work during the nine years since she had left Germany he invited her to deliver at Stockholm a course of lectures on partial differential equations. Meanwhile he succeeded in obtaining the money necessary to establish and sustain a chair of higher mathematics, created especially for her. She lectured the first year in German, afterwards in Swedish. Her clear, inspiring teaching, her intellectual ability, and her personal popularity attracted to her classes many able students, some of whom were already professors. In 1885 she was made associate editor of *Acta Mathematica*, and later was elected corresponding member of the Royal Academy of Science of St. Petersburg. The French Academy proposed as the subject of the Bordin prize in 1888 the problem "To complete in an important point the theory of the motion of a solid body." The commission not only unanimously awarded her the prize, but upon their recommendation the amount was increased from 3,000 to 5,000 francs on account of the "extraordinary service rendered to mathematical physics by this work." She traveled in all parts of Europe, making friends wherever she went, and continued to fill her position at Stockholm until February of last year. After only four days' illness she died of pleurisy Feb. 10, 1891, at the age of thirty-seven.

Her mathematical works consist of the following papers:—

I. On the Theory of Partial Differential equations (Thesis for Ph. D.),—published 1875. *Journal fur die reine und angewandte Mathematik*, Vol. LXXX, p. 1 (32 pp.).

II. On the Reduction of a certain class of Abelian Integrals of the third Rank to Elliptic Integrals,—published 1884. *Acta Mathematica*, Vol. IV, p. 393 (22 pp.).

III. On the Propagation of Light in a Crystalline Medium,—published 1884. "*Ofversigt af svenska veterskapsakademiens forbandlingar*, Vol. XLI, p. 119 (3 pp.).

IV. On the Propagation of Light in a Crystalline Medium,—published 1884. *Comptes Rendus*, Vol. XCVIII, p. 356 (2 pp.).

V. On the Refraction of Light in Crystalline Media,—published 1885. *Acta Mathematica*, Vol VI, p. 249 (56 pp.).

VI. Remarks and Observations on Laplace's Researches on the Form of Saturn's Rings,—published 1885. *Astronomische Nachrichten*, Vol. CXL, p. 37 (12 pp.).

VII. On the Problem of the Rotation of a Solid Body about a Fixed Point,—published 1889. [Résumé of IX.] *Acta Mathematica*, Vol XII, p. 177 (56 pp.).

VIII. On a property of the system of differential equations which defines the rotation of a solid body about a fixed point,—published 1890. *Acta Mathematica*, Vol. XIV, p. 81 (13 pp.).

IX. Memoir on a particular case of the problem of the rotation of a heavy body about a fixed point, where the integration is effected by aid of the hyperelliptic function of the time,—published 1898. *Recueil des Savants etrangers*, Vol. XXX, p. 1 (66 pp.). [This is the work crowned by the French Academy.]

X. On a theorem of Mr. Bruns. *Acta Mathematica*, Vol. XV, p. 45 (19 pp.).

She wrote seven literary works.

I. The Private Teacher, published anonymously as an appendix in a Russian journal.

II. Reminiscences of Geo. Eliot. *Rousskaia Mysl* (Russian Thought), July 1885.

III. Vae Victis. Novel published in Swedish in the journal *Jul Almanack*, 1889.

IV. Recollections of Childhood (in Russian), 1890. *Vestnik Europy* (Messenger of Europe), Vol. 7-8, 1890.

V. The Rajevsky Sisters, 1890. The same as IV, but published in the form of a novel in Swedish and in Danish.

VI. The Family of the Vorontsoffs. 1890. Novel in Swedish under the pseudonym of Tanja Rajevsky. It was left complete in manuscript, and the first chapters had been published in the Swedish journal, *Nordisk Tidskrift*.

VII. The Struggle for Happiness. 1890. Under this title two dramas were written jointly by her and Anna C. Leffler, (wife of P. de Pezzo, duke of Cajanello, who is professor of higher geometry in the University of Naples).

In her thesis on partial differential equations, Mme. Kowalevski extended Weierstrass's method of proving the existence of an integral of a given system of ordinary differential equations, and proved the exitsence of an integral of a given partial differential equation. Also she showed in general that the original functions can be expressed in a series of integral powers of the independent variable convergent within a determinate circle, and discussed carefully the case in which this series becomes divergent.

The Commission of the French Academy, before they knew the name of the author, gave the following summary of the memoir which received the Bordin prize: "This remarkable work contains the discovery of a new case in which we may integrate the differential equations of the motion of a heavy body fixed by one of its points. The author is not content with merely adding a result of the highest interest to those which we have had transmitted by Euler and by Lagrange. He has made, from the discovery which we owe to him, a profound study, in which are employed all the resources of the modern theory of functions. The properties of the theta-functions of two independent variables permit of giving the complete solution in the most exact and elegant form; and we have thus a new and remarkable example of a mechanical problem, in which these transcendental functions occur, whose applications have been hitherto limited to pure *analysis or to geometry*." The President of the Academy, M. Janssen, in announcing the decision of the commission, said, "Our associates of the section of Geometry, after examining the memoirs presented in competition, have recognized in their work, not only the proof of a knowledge extensive and profound, but also the mark of a great inventive mind."

In Kronecker's editorial in *Crelle* we find the following general estimate of Mme. Kawalevski: "She united with an extraordinary talent, as well for general mathematical speculation as also for the technical knowledge necessary in special researches, tireless industry; and, in spite of the most intense activity, in her specialty, her mind was always open to other intellectual interests, and she preserved always therewith her womanliness, and gained and held also the sympathy of those who stood outside the circle of her special knowledge. The history of mathematics will have to speak of her as one of the most noteworthy lights among the class of original investigators everywhere extremely rare. While her memory will endure in the entire mathematical world through her published works (not numerous indeed, but very valuable), the memory of her remarkable and charming personality will live on in the hearts of all those who had the pleasure of knowing her."

NOTE.—The above paper is founded on the following four sketches, all published in 1891:—*Annali di Mathematica, Milano*, 1891, Vol. XIX, No. 3, pp. 201-11. By Anna C. Leffler, Duchess of Cajanello.—*Rendiconti del Circolo Matematico di Palermo*. Vol. V, No. 3, pp. 121-28. By Mme. E. de Kerbedz.—*Journal fur die reine und angewandete Mathematik, Berlin*, 1891. Vol. CVIII, No. 1, p. 88. Editorial by Kronecker.—*Nature*, Feb. 19, 1891, pp. 375-6. The following are promised:—Sketch with portrait in *Acta Mathematica*.—Continuation of *Reminiscences of Childhood*, from the date of her marriage. Edited by Anna C. Leffler, Duchess of Cajanello.

HISTORICAL NOTE RELATING TO THE SEARCH FOR THE PLANET NEPTUNE IN ENGLAND IN 1845-6.

BY EDWARD S. HOLDEN.

In 1876 I was in England for several months and one of my greatest privileges was the acquaintance and friendship of Mr. Lassell, the celebrated astronomer, whom I frequently visited. During one of my visits to Ray Lodge I learned the following circumstances from Mrs. Lassell, and they were subsequently confirmed and explained to me by Mr. Lassell himself.

With the innate delicacy of his character he had taken every precaution that they should not become known during the lifetime of Professor Adams, and I think he seldom or never alluded to them. At this time, when the great mathematician has gone from us, it seems to be right that they should be mentioned and, with the permission of the Misses Lassell, I reproduce in what follows the brief notes I made at the time of Mr. Lassell's confidences, as a contribution to the history of the great discovery of Adams and of Le Verrier.

It is known that in October, 1845, Professor Adams, then an undergraduate of Cambridge, submitted to Sir George Airy, Astronomer Royal, the results of his computations on the perturbations of *Uranus* and the elements of a new planet—*Neptune*—which would account for the observed disturbances in the orbit of the former.* The distinguished observer, the Rev. W. R. Dawes, visited the Royal Observatory about this time, and the letters and computations of Adams were shown to him by Airy. It is known that the Astronomer Royal had, very naturally, grave doubts as to the sufficiency of these researches; but it appears that Dawes was much impressed by the letters of Adams, and that he at once wrote to Lassell to beg him to search for *Neptune*, in the region designated by Adams, with his powerful two-foot reflecting telescope (which was then mounted at Starfield, near Liverpool).

There is no doubt whatever if such a search had been made by such an observer and with such a telescope, that the planet would have been quickly found and recognized by its disc. We have but to remember that to the same telescope and observer we owe the discovery not only of the satellite of *Neptune* but also that of the two inner and faint satellites of *Uranus*.

It chanced that the letter of Mr. Dawes reached Liverpool when Mr. Lassell was confined to his sofa by a sprained ankle,

* See Gould on the history of the Discovery of *Neptune*. Washington, 1850.

and that it was laid on his writing table near by for subsequent attention. Mr. Lassell, also, was impressed with the importance of a search for the predicted planet and had fully resolved to make such a search.

After his recovery he sought for the letter of Mr. Dawes which gave the predicted place of the planet. The letter could not be found as it, together with some other papers, had been removed and destroyed by a too zealous maid-servant.

I think, though I am not sure, that renewed inquiry was made by Lassell of Dawes as to the data in question. However this may have been, they were never recovered, and the mistaken zeal of the maid-servant had its full effect.

The new planet was never sought for by the most powerful telescope and the most skilful observer in England. The search of Challis, at Cambridge, was fruitless, as is well known. The planet was finally found by Galle and D'Arrest, at Berlin, on September 23, 1846, after the Berlin Observatory had received the letter of Le Verrier pointing out its situation.

This was many months after the letter of Dawes to Lassell.

This incident of the history of the search for *Neptune* is well worthy of record, as it shows by what a narrow chance Professor Adams escaped the distinction of being the *sole* discoverer of *Neptune*.

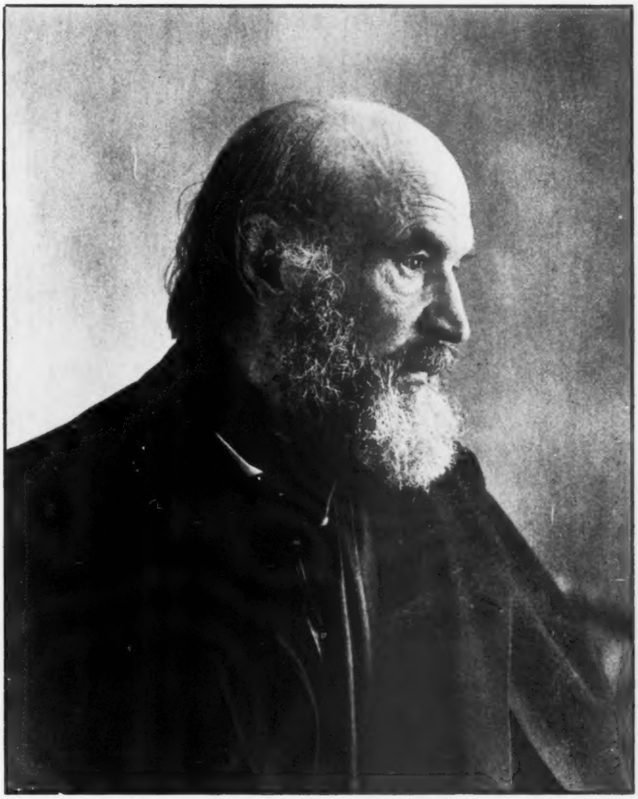
It is also worthy of remark how this and other accidents have helped to forward the Science of Astronomy. England had no higher rewards and opportunities to offer than those which she has given to Adams. But if Le Verrier had been deprived of his share in the discovery it is very much to be doubted whether we should now possess that long series of elegant and laborious researches which he was able to carry out by the facilities afforded him in his situation as head of the National Observatory of France.

The whole relation of Professor Adams to this great discovery is again called up by this incident and the elevation of his character and the dignity of his conduct are again brought to mind.

The delicate consideration of Mr. Lassell, who for a long lifetime kept this secret in order that no possible shade of regret should be inspired during the lifetime of Professor Adams, is no less honorable. It is a pleasure to be able to link in this way the name of England's great mathematical astronomer with the name of her great observer—worthy successors of Newton and of Herschel as they were.—*Pub. of Astr. Soc. Pacific, No. 21.*

MT. HAMILTON, Jan. 30. 1892.

NOTE: By the great kindness of a friend in England I am able to reproduce here the last picture taken of Professor Adams, which was made in Cambridge in September, 1891.



PROFESSOR JOHN COUCH ADAMS.

SEPTEMBER, 1891.

Plate by the kindness of Professor E. S. Holden, Lick Observatory.

ASTRONOMY AND ASTRO-PHYSICS, April, 1892.

ASTRO-PHYSICS.

OBSERVATIONS OF THE NEW STAR IN AURIGA, MADE AT PRINCETON, N. J.*

PROFESSOR C. A. YOUNG AND TAYLOR REED.

On Saturday, Feb. 6, the spectrum was observed with the 23-inch telescope and a single-prism Clark spectroscope, without cylindrical lens. The sky clouded, however, before a set of measures could be made.

C was vivid; D (?) distinct. There were two knots of luminosity between C and D, and I strongly suspected another a short distance below C. Near b and below it four bright lines or bands were easily made out, and two more between b and F. F was conspicuous, and $H\gamma$ (near G) was obvious. There was a faint line about one-third of the way from G towards F; and I thought I could glimpse h ($H\delta$). In all thirteen bright lines were fairly seen between C and F inclusive, and two others were suspected outside those limits.

Bad weather and other circumstances prevented further observations until Feb. 12, when a series of measurements was made with the 9½-inch telescope and the Clark spectroscope, by means of the scale and occulting bar. The constants of the scale were determined by reference to the spectrum of the Moon. Ten lines were measured with the results for wave-length which are given in the appended table.

On the 13th, a second set of measures was made with the 23-inch, and a single reflecting prism of Hastings' design, on the Brashear spectroscope. The prism is moved by a tangent-screw which carries a vernier over a graduated circle, and the measures were made by bringing the lines to the faintly illuminated cross wires of the micrometer and reading the circle, the reference points being obtained from the spectrum of the Moon as before. The method proved rather unsatisfactory, the graduation of the circle not being fine enough to correspond with the optical power of the apparatus: the results for the eight lines measured are given in the table.

Before the Hastings' prism was put in place, the brightest part of the star spectrum was examined with the Rowland grating of 20,000 lines to the inch, in order to determine whether the lines

* Communicated by the author.

were true *lines*, or whether they were *bands*, sharply defined on the more refrangible edge, and fading away towards the red. An impression of this sort had been received from some of the observations with the small spectroscope, but it was found to be incorrect. The lines were diffuse indeed, like C and F from hydrogen under some pressure; but the shading was sensibly symmetrical each way from the middle of the line. The two lines nearest F (4922 and 5015) made the impression of being *multiple*; but they were not bright enough to permit a narrowing of the slit sufficient to settle the question.

On Feb. 15th, the same instruments were used as upon the 13th, but a different plan of work was adopted, by limiting the measures to a single field of view, extending from F to some distance below; the special purpose being to determine whether or not the two principal nebula lines (λ 5004 and 4957) were present in the star spectrum. The prism was firmly clamped, and the measures were made wholly by the micrometer, the reference points being derived from the nebula of Orion and the Moon. The results for the six lines measured are given in the table, and may, I think, be depended upon with an error not to exceed one, or possibly two, in the last figure. It was intended to extend the measures to other parts of the spectrum, but clouds prevented.

I regret extremely that the non-completion of the prism-train for the Brashear spectroscope made it impossible to attempt photographs of the spectrum.

As regards the identification of the lines, C, F and $H\gamma$ are beyond doubt. One would expect to find D_3, but the measures seem to indicate a lower position for the bright line observed, not far from the sodium lines themselves. It may be worth noting that the red line at 632 and the yellow one at 559 (according to the measures) are near the positions of the two aurora lines at 557.1 and 630*, possibly within the limits of error. The line at 449 may perhaps be the always present chromosphere line known as f, (λ 4472), or, perhaps more probably may correspond to the three lines at 4490 and 4501; indeed, it is not unlikely that all four ot the lines named might be confounded into a single diffuse band in observing that faint part of the spectrum with (necessarily) rather widely opened slit.

As regards the lines in the green the micrometer readings seem to be irreconcilable with the presence of the two brightest nebula lines. The lines at 5015 and 4957 are more probably identical

* My own observation of the wave-length of this line on Feb. 13th made it 633.5.

with two rather remarkable groups of lines frequently present in the chromosphere spectrum at 5015-18, and 4918-23 respectively. The line at 5165 is almost coincident with b_4 (5167), but the absence of the other magnesium lines makes the identity improbable. The line at 5304 is not far from the corona line (5316), but the difference appears to be quite beyond the possible limit of error. The line at 5260 was very faint and its position is not so well determined as the other four figure places. It falls very near E.

On Feb. 6th the star was easily visible to the naked eye, and was estimated as about a quarter of a magnitude brighter than χ Aurigæ; by the 15th it had fallen off very sensibly, and was about a quarter of a magnitude fainter than χ.

From six meridian circle observations of the star in connection with β Tauri, Mr. Reed has found for its mean place, Jan. 1, 1892, $\alpha = 5^h\ 25^m\ 3^s.30$, $\delta = +30° 21' 49''.2$.

Bright lines in the Spectrum of Nova Aurigæ—α $5^h\ 25^m\ 3^s.30$; δ 30° 21′ 49″.2. [1892.0].

Date	1	2	3	4	5	6
Feb. 12	434 (Hγ)	449	486 (F)	493	501	516
" 13	......	......	486	492	502	515
" 15	......	......	4861	4922	5015	5165

Date	7	8	9	10	11	12
Feb. 12	......	531	559	588, D?	faint	656 (C)
" 13	faint	530	......	591	631	656
" 15	5260	5304	......	......	......	......

PRINCETON, Feb. 20, '92.

THE TEMPORARY STAR IN AURIGA.*

G. RAYET.

The temporary star in Auriga, the existence of which was announced by a telegram from Mr. Copeland dated February 1st, and which was discovered by an anonymous amateur, has been observed twice with the instruments of the Bordeaux Observatory, on the 10th and 11th of February.

The position of the new star for 1892.0 is: R. A. $5^h\ 25^m\ 3^s.47$, P. D. 59° 38′ 9″.5.

The new star is not given in Argelander's zones, and it is therefore probable that its previous magnitude was less than the 9th.

* Translated from *Comptes rendus* (Paris), Feb. 15, 1892.

On the 10th and 11th, the star was about 5th magnitude, comparable with 26 Aurigæ; its color was noted as yellow orange or straw yellow.

The spectrum of the star, which I have examined twice with a spectroscope having a single prism of heavy flint, and mounted on the 14-inch Bordeaux equatorial, consists of a continuous spectrum, in which the red and violet seem very brilliant, with four bright lines or bands in the green. My measures give the following wave-lengths for these lines:

First line	518 $\mu\mu$ near b; probably b.
Second line	501
Third line	493
Fourth line	487 near F; very probably F.

The second and third lines are the brightest; they have, as is always the case, a banded appearance.

The spectrum of the new star in Auriga differs very sensibly from that of the new star in Corona (May, 1866) observed by Huggins, M. Wolf and myself; from that of the star in Cygnus (November, 1876) described by Vogel, Cornu, Copeland and Backhouse; and, finally, from that of the star in Andromeda (August, 1885) studied by Vogel, Maunder and Perry. The light of all these stars showed bright lines in the red and violet, particularly the lines Hα and Hβ of hydrogen; the lines of the present star are all four comprised between b and F. It must be remarked, however, that in the case of the star in Cygnus, the outer lines of hydrogen disappeared before F and the line 501$\mu\mu$; this, perhaps, explains why the Hβ line is the only one visible in the light of the star in Auriga.

P. S. A new observation, made on the night of February 14-15, allows me to add to the four preceding lines the bright line Hα of hydrogen in the red, and that of sodium.

THE MODERN SPECTROSCOPE.

IV.

*The New Spectroscope of the Halsted Observatory.**

PROFESSOR C. A. YOUNG.

Through the liberality of one of the best friends of Princeton College the Halsted Observatory has lately received a powerful

* Princeton College Bulletin, November, 1891.

spectroscope, which in several respects is more perfect and complete than any other before constructed. It has been designed as a sort of universal instrument, to cover, as nearly as possible with a single apparatus, all the ground of Astronomical Spectroscopy. It is arranged for solar work, either in the study of Sun-spot or chromosphere spectra, or for the observation of the prominences; also for the study of stellar spectra with high dispersion in order to follow up the work of Vogel and others upon the motion of stars in the line of sight; and it has a low-dispersion prism which makes it available for observations upon the spectra of comets or other faint objects. Moreover, the construction is such that the observations can be made either visually or photographically.

Naturally, the attempt to cover so much ground with a single instrument renders it somewhat complicated; but it has not been necessary to sacrifice, nor even seriously to compromise, any one object in order to attain others.

The instrument has been constructed by Mr. Brashear of Allegheny, the same optician who made the spectroscope for the Lick Observatory; and great credit is due him and his foreman, Mr. Klages, for the great skill and ingenuity with which they have carried out the general plan, and for the admirable accuracy and finish of the workmanship.

A stiff but light framework of four steel tubes carries the spectroscope, and is attached to the great telescope by two rings which slip over the seven-inch brass tube that forms its tail-piece. This mode of attachment permits the spectroscope to be rotated freely around the optical axis of the great telescope, and to be clamped firmly in any position. The collimator is mounted centrally in this framework in such a way that it can be adjusted with respect to the optical axis, and also can be moved longitudinally a distance of about four inches in order to bring the slit-plate accurately into the focal plane for rays of any color. (The focus of the 23-inch object-glass for the violet portion of the spectrum near the lines H and K is more than three inches beyond the focus for the green rays).

The slit-plate is an elaborate and beautiful piece of workmanship; the jaws of the slit are most carefully finished, and there are arrangements for varying the opening from zero to half an inch in width, and from zero to an inch in length, as well as for moving it sideways. The plate carries a set of colored screens which can be interposed at pleasure; also (when needed) a "comparison reflector" for throwing into the slit the light of an elec-

tric spark, the electrodes between which the spark is formed being carried by a holder attached to the steel tubes of the supporting frame. There is also a "rotation prism," which can be attached at pleasure, and enables the observer to make any portion of the Sun's limb parallel to the slit without having to rotate the spectroscope into uncomfortable positions.

The collimator has an object-glass two and a half inches in diameter, with a focal length of thirty inches, and the same is true of the view telescope. This is supported by a pair of light but stiff arms which are firmly attached to the steel tubes, and it is held by these arms in such a position that it receives centrally the rays from the grating or from the prism-train as the case may be. When the grating is in use a short pair of arms is used which holds the view-telescope in a rigidly fixed position; when the grating is replaced by the train of four prisms used in stellar work, a second and longer pair of supports is substituted, so arranged as to permit the necessary motion of the view-telescope over a considerable arc, but with the means of clamping it firmly in any position. The necessity of making such a change is of course objectionable, but it is unavoidable, and Mr. Brashear has ingeniously reduced the inconvenience to a minimum without sacrificing the indispensable firmness.

The collimator and view-telescope are each provided with two separate object-glasses, one pair to be used for all visual observations, the other for photography. It was originally intended to have but one pair, with the component lenses made of the new Jena glass, giving a practically perfect color-correction through the whole range of the spectrum. But Mr. Brashear, after considerable experience in the matter, has reluctantly come to the conclusion that it is not yet practicable to construct such lenses, or rather that such lenses when constructed cannot be relied on to keep their polish for any great length of time; the glass soon "rusts."

The tube of the view-telescope is made in two sections, so that the eye-piece end with its micrometer can be easily removed and replaced with a camera tube carrying a 4 × 5 plate-holder.

In focussing the spectroscope the two object-glasses of the collimator and view-telescope, are moved simultaneously and equally by a very ingenious arrangement which couples them together and still leaves the view-telescope all the necessary freedom of motion. It may be stated here that all the instrumental adjustments of every kind are managed by milled heads easily accessible by the observer without removing his eye from the eye-piece.

also that there are graduated scales to each important adjustment, so that a record can be made of the precise state of the instrument at any observation.

For solar work the "dispersion piece" is a magnificent five-inch Rowland grating of 20,000 lines to the inch ruled on a speculum metal plane. The definition of this grating is superb, and its spectra are remarkably free from "ghosts," though not absolutely so. At present, through the kindness of Mr. Brashear, we have also on loan a second, smaller but very fine grating of 14,400 lines to the inch, which can be at any time substituted for the other, and used for verifications. The grating is so mounted that it can be rotated by the observer in the plane of dispersion as usual, and also so that it can be slightly adjusted in a plane at right angles to this, as is sometimes necessary, and this, as has been said, without taking the eye from the instrument.

The prism for comet work has faces about 3½ inches by 3, with a refracting angle of about 25°; it is silvered on the back, and when substituted for the grating furnishes by reflection a short but brilliant spectrum, without requiring any other change of adjustment or arrangement.

For observation of stellar spectra there is a train of four large compound prisms of Jena glass faced with wedges of crown glass. The faces of the prisms measure about two and a half inches by three, the back of the prism being fully four inches long. The angles are calculated to transmit the H and K lines of the spectrum with a minimum deviation of about 165°. The prisms are mounted in a metal box, and connected with each other in such a way that the adjustment for minimum deviation is easily made for all four at once by simply moving a sliding rod at the eye end of the view-telescope. When this prism is used the grating-box with its appendages is removed and the prism-box substituted; the view-telescope also has to be taken off and replaced with the proper supporting framework. The whole operation can be performed in less than ten minutes.

The optician has encountered considerable difficulty in connection with these prisms; one of the four originally sent proved to be unsatisfactory on account of unequal density in the glass, and the prisms are now in the maker's hands to have the faulty one replaced. Nothing, therefore, has yet been done with the instrument used as a prismatic spectroscope.

With the grating some preliminary work has been done, both in the way of visual observations and by photography. About fifty plates have been exposed, more or less successfully, and a

considerable number of good negatives have been obtained, mostly relating to the ultra-violet portion of the spectra of the chromosphere and prominences, with a few spectra of Sun-spots.

The plates confirm entirely the results first photographically reached by Hale of Chicago early last summer, and since then by Deslandres in Paris, as to the constant and brilliant reversibility of the H and K lines in the spectra of Sun-spots, and of the chromosphere and prominences. (The fact of this reversibility had been known ever since 1872 as the result of the *visual* observations made by the writer at Sherman, Wyoming.) The photographs also show, as do those of Hale and Deslandres, in the spectrum of the solar chromosphere, the remarkable ultra-violet series of bright Hydrogen lines which are so conspicuous and characteristic as dark lines in the spectra of the stars of the first or Sirian type, but are hardly visible in the spectrum of the photosphere of the Sun, and in the spectra of the Sun's stellar congeners.

A partially successful attempt has also been made to photograph the spectrum of a star with a grating; in the negative of the spectrum of Vega, made with an exposure of half an hour, the principal lines are unmistakably visible; but the impression is extremely faint, and the result is interesting only as being, so far as I know, the first instance in which any impression at all has been obtained of a star-spectrum by means of a grating.

As a first fruit of visual observations with the new instrument may be mentioned the discovery that the bright red line, which often appears in the active prominences at 6679 of Angstrom's scale, (No. 2 of the catalogue of chromosphere lines), is distinctly less refrangible than the Iron line of which it has hitherto been supposed to be the reversal. The behavior of this line has always been a mystery, since there was no obvious reason why it should behave so differently from the other Iron lines of the spectrum near it. It is now certain, however, that, whatever may be the substance to which this line is due, it is not Iron.

ON THE LIMIT OF VISIBILITY OF THE DIFFERENT RAYS OF THE SPECTRUM.*

CAPTAIN W. DE W. ABNEY.

In certain photometric experiments it became necessary to find the limit of visibility of the different parts of the spectrum, and

* Proceedings Royal Society, No. 301.

PLATE XI.

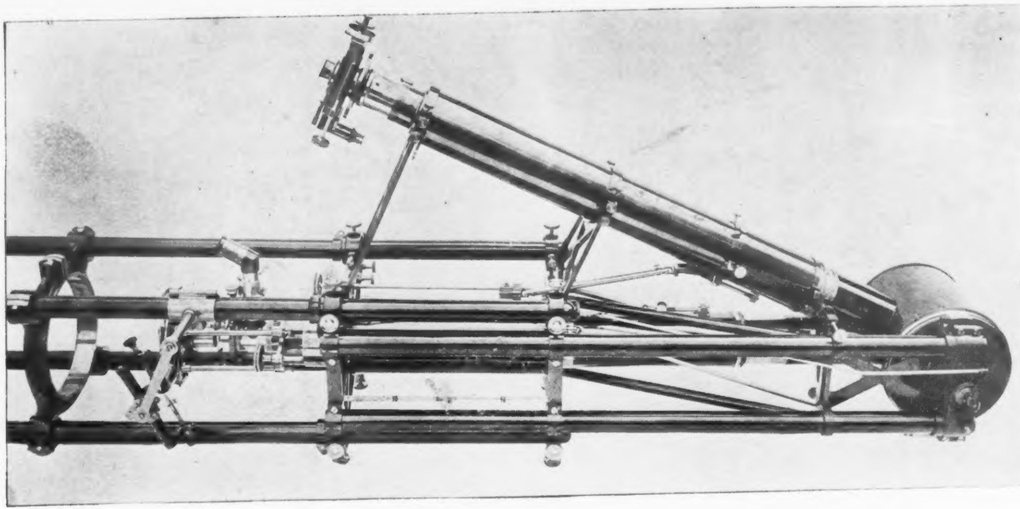


Plate accompanying Professor Young's paper on the New Spectroscope of the Halsted Observatory.

Astron. and Astro-Physics, March, 1892.

also to ascertain what ratio this limit would bear to some fixed luminosity. It should be borne in mind that this question is totally different from acuteness of vision, which some have confounded with it. The two are independent one of the other, and can scarcely be compared.

The instrument used in these experiments was similar to that described in the note on the examination of a case of Tobacco Scotoma, &c., but the dimensions were modified:—A square tube, 3 feet long, had an aperture of 2 inches cut in its side at 2 feet 6 inches from one end, and covered over with ground glass. Within the tube, and close to the ground glass, was a mirror, which reflected the light coming through the ground glass on to the end of the tube, and if the ground glass was illuminated by any light the reflection illuminated a card placed at the end of the tube. The illumination of the card could be viewed through a circular hole at the other end of the tube, in which was fixed a smaller tube, fitting closely into the eye. If a color patch from the spectrum was thrown on to the ground glass, evidently the card at the end of the tube would be illuminated by the color used, and its disappearance could be effected by means of rotating sectors closing and opening at will, placed in front of the patch. This simple piece of apparatus answered its purpose most effectively.

The first point to ascertain was the ratio of illumination of the card to that of the patch thrown on the ground glass. The following arrangement was made to effect this. The end of the tube, against which the card was placed, was removed, and a card with a square hole, of ¾-inch side, was inserted instead. This was covered on the side away from the tube with a piece of Saxe paper, and when viewed from the outside, and when illuminated by the light from the ground glass, showed as a square patch of light. Outside of this, and of double the width, but of the same height, a mask of black paper, with an oblong aperture, was placed so that the illuminated square occupied one-half of the oblong, and the other half showed no white paper. An amyl acetate lamp (0.8 of standard candle), placed at a fixed distance from this oblong, and in a line with the axis of the tube, illuminated both squares; but a rod placed in proper position cast a shadow on the translucent square, allowing only the opaque white half to be illuminated. When the sectors above alluded to were placed in front of the lamp, the two brightnesses could be equalized, and the intensities of the light transmitted passing through the paper estimated.

Now there is a ray very near D in the spectrum, whose color is very closely, if not quite, identical with the color of the light emitted by the burning amyl acetate, and for making the measures this ray was used. When the measure had been made, the screen, with the square aperture, was placed in the position of the ground glass, and the amyl acetate lamp placed on the side of the screen, away from the color patch, and the rod placed in position to cast the shadow necessary. The rotating sectors were then placed between the spectrum and the screen, and the light reduced so that the illumination of the translucent and opaque white square, *viewed from the side of the lamp*, was equalized. Knowing the distance of the lamp in the two cases, and the aperture of the sectors, the relative illumination of the two surfaces was ascertained. For convenience, the aperture of the ground glass was limited by means of a diaphragm, or by placing a diaphragm in front of the first prism.

Two sets of measures showed that if the illumination of the ground glass be represented by 1, the illumination of the card at the end of the tube was $\frac{1}{700}$; that is, any light falling on the ground glass was diminished to that extent.

The actual measures were $\frac{1}{690}$ and $\frac{1}{714}$, but we may take $\frac{1}{700}$ as sufficiently close to the truth.

The color-patch apparatus to which reference is made is described in the Bakerian Lecture, 1886 (Abney and Festing, "Color Photometry"). The only addition to it that was made was to use an adjustable slit to move through the spectrum. There was thus a treble means of altering the intensity of the light, viz., by altering the aperture of the slit of the collimator, by altering that of the slit of the slide, which was shifted at will into different parts of the spectrum, and by the rotating sectors placed in front of the spectrum. The mode of proceeding to measure the luminosity at which light disappeared was as follows :—The dullest part of that portion of the spectrum which it was desired to extinguish was allowed to pass through the slit in the spectrum, and a patch was formed on the ground glass, which, it may be remarked, had a tube fitted over it, to prevent any chance of extraneous light reaching it. The card at the end of the square box was viewed, and the slits closed till all trace of light disappeared. (It may be as well to call to mind what is well known, that faint light of all colors appears as white). In some sets of experiments the sectors were set at fixed angles, and rotated in front of the patch, and the slit in the spectrum moved from a position in which faint light appeared to one in which it

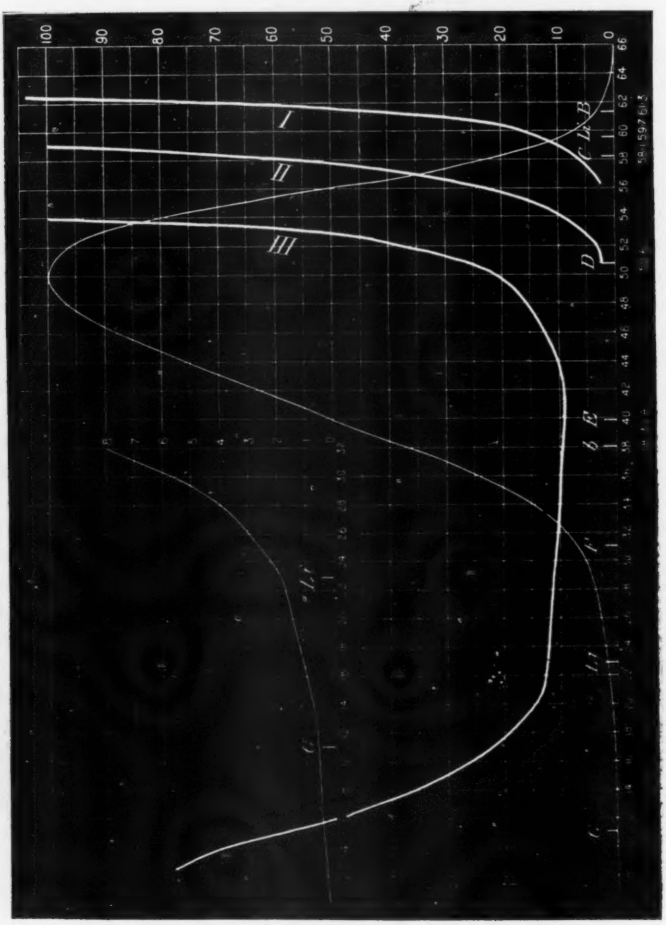
just disappeared, the position in the spectrum being noted by the scale at the back of the moving slide carrying the slit. In other cases the slit was placed at different positions in the spectrum, and the rotating sectors closed till all light had vanished, when the aperture was noted. The first plan is the more convenient of the two, and gives very accurate results; though in some positions of the spectrum the second method must be adopted, since the graphic curve formed from the readings becomes almost a horizontal straight line at one portion of the spectrum. As wil be seen from the table, it is quite evident that no one aperture of the slit of the collimator and of that in the slide would suffice to give the entire range of disappearance of the spectrum, and that at least three settings are necessary. At each change the D light falling on the ground glass was measured, and the necessary factors to make the readings on one scale were derived from these measurements.

Four sets of measures throughout the spectrum were made on different days. No one differed to any appreciable extent from the other. A mean of the four has been taken as representing the truth, and the measures given in the first table are those of that which most nearly approaches this mean. It may be stated that very rarely did one curve differ more than 4 per cent. from another at any portion of the spectrum. The readings were taken when the eye had rested in darkness some time, and were often repeated a considerable number of times, the first parts measured being re-measured last. That the eye was equally sensitive throughout the time may be judged from the fact that the two sets of readings scarcely ever differed. The process of making these measures of extinction is very fatiguing, and probably rather detrimental to the eyesight; owing to the strain on the eyes, one set of readings is usually as much as can be properly carried out on any one day, if accurate results are to be looked for.

It is now three years ago since I began this research, and, after trying various plans, I have come to the conclusion that the method now described is the most easy, as it is the most simple.

There is one point in the method which might be open to criticism, and that is that the cutting off the light by rotating sectors might cause some error in the results. This criticism, I may say, I raised in my own mind at its very commencement, and found that it was unnecessary. Polarising the light entering the slit of the collimator, and then dimming it by means of a Nicol's prism placed in front of the color patch, proved an un-

satisfactory method for answering the criticism, as in no case could a total disappearance of a bright light be brought about; but by diminishing the area of the color patch by placing different apertures of diaphragms in front of the last prism of the



The ordinates of Curve II are ten times that of I, and of Curve III 100 times that of I.

color-patch apparatus (and thus throwing on the ground glass discs of light of various areas), the truth of the results was readily verified. The two sets of measures, one made in this way

and the other as just described, gave identical results within the limits of the errors necessarily due to observation.

The method adopted gave the extinction of light on the whole retina, for not only was the central part used, but the extinction was carried so far that it was complete for every part of the eye. As there is a considerable absorption in the yellow spot this is necessary, but the absorption exercised in this part of the eye, which occupies from 4° to 6° angular aperture, can be fairly measured if only the light on a small area be extinguished and this part of the retina be alone used. A very simple way of see-

TABLE I.

No. 1.

Scale No.	Sector aperture.	Sector aperture reduced.
55.2	180	180
5.3	180	180
54.0	90	90
9.3	90	90
53.2	60	60
10.6	60	60
52.3	45	45
13.3	45	45
51.3	32	32
15.9	32	32
50.5	25	25
16.3	25	25
50.0	22.5	22.5
17.3	22.5	22.5
48.4	15	15
19.3	15	15
45.4	11	11
26.3	11	11

D light had to be reduced to 0.17789 its luminosity to equal the light from an amyl lamp at 48 cm. from the ground glass.

No. 2.

Scale No.	Sector aperture.	Sector aperture reduced.
57.3	180	456
2.1	180	456
55.9	90	228
4.3	90	228
54.1	38	97
8.3	38	97
53.1	20	51
12.3	20	51

Luminosity of patch on No. 2 = 2.56 that of No. 1.

No. 3.

60.8	180	2700
..	..	..
59.4	90	1350
58.3	45	675
56.9	22.5	337
53.4	5	75

Luminosity of patch No. 3 = 15 that of No 1.

No. 4.

Scale No.	Sector aperture.	Sector aperture reduced.
52.3	180	45
14.3	180	45
49.8	90	22.5
17.3	90	22.5
44.3	45	11.25
26.3	45	11.25
43.3	40	10
35.3	40	10
25.3	45	11.25
30.3	43	10.75
34.3	40	10
38.3	37	9.2

Luminosity of patch in No. 4 = 0.25 that of No. 1.

No. 5.

61.9	180	6000
60.9	90	3000
60.2	60	2000
59.0	30	1000
57.6	15	500
56.5	9	300

Luminosity of patch in No. 5 = 22.2 times that of No. 1.

A measure showed that 63 required double the aperture of 62 to be extinguished.

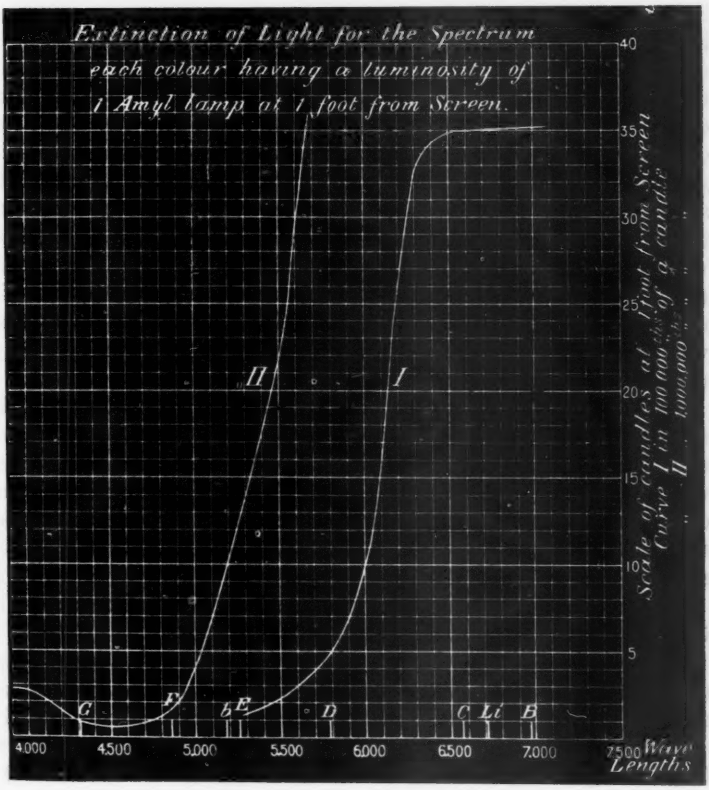
ing the absorption of the yellow spot is to form a feeble spectrum some 3 inches long on a ground-glass screen. If the eye looks at the green, a dark band extending to the blue will be seen, but if the eye be turned towards the red end or violet, the green is seen outside the central spot and the color reappears. I propose to return to this in a fuller discussion of the subject.

TABLE II.

Extinction of Rays of Equal Luminosity, the Luminosity being 1 Amyl Lamp at 1 foot from a Screen.

Scale No.	λ.	Reading.	Luminosity of rays.	Extinction of equal luminosities.	.00001 of an amyl lamp 1 ft. off screen.
63	7082	13,000	1	13,000	36.11
62	6957	6,400	2	12,800	35.5
61	6239	3,100	4	12,400	34.4
60	6728	1,800	7	12,600	35.0
59	6621	1,000	12.5	12,500	34.7
58	6520	600	21	12,600	35.0
57	6423	380	33	12,540	34.8
56	6330	240	50	12,000	33.3
55	6242	160	65	10,400	29.0
54	6152	100	80	8,000	22.2
53	6074	55	90	4,950	13.75
52	5996	38	96	3,640	10.11
51	5919	28	99	2,772	7.70
50	5850	21	100	2,100	5.83
49	5783	17	99	1,682	4.65
48	5720	16	97	1,552	4.31
47	5658	14	92.5	1,294	3.59
46	5596	12.4	87	1,078	2.99
45	5535	11.6	81	906	2.517
44	5481	10.0	75	750	2.083
43	5427	9.8	69	686	1.905
42	5373	9.6	62.5	600	1.666
41	5321	9.6	67	546	1.516
40	5270	9.6	50	480	1.333
38	5172	9.6	36	346	0.911
36	5085	9.8	24	236	0.655
34	5002	10.0	15	150	0.4166
32	4924	10.2	8	82	0.2277
30	4845	11.0	5.5	50	0.1388
28	4776	11.2	4	43.6	0.1166
26	4707	11.6	3	35	0.0972
24	4643	12.0	2.2	26.4	0.0733
22	4578	12.4	1.6	20	0.0555
20	4519	14.0	1.4	18	0.0500
18	4459	18	1.2	21.6	0.0600
16	4404	26	0.9	23.4	0.0650
14	4349	36	0.7	25.2	0.0700
12	4298	50	0.6	30	0.0833
10	4247	70	0.55	36.4	0.1011
8	4197	104	0.5	52	0.1444
6	4151	160	0.4	64	0.1777
4	4105	240	0.35	84	0.2333
2	4058	350	0.3	105	0.2916
0	4010				

The first table shows the actual observations in the spectrum. The second table attached shows the extinction of light of a luminosity of one amyl lamp placed at a foot from the screen. It will be seen that the extinction of the red rays is effected when they are reduced to about 36/100,000 of this standard, whilst the rays near F require a reduction of 5/10,000,000, that is, the sensitiveness of the eye is 700 times greater for the latter color than the former, and this has a bearing on the extinction of white light of different qualities.



It is worthy of remark that the reduction of the rays from about C to the visible limit of the red necessary to cause extinction from the standard luminosity is practically the same, and points to the fact that this part of the spectrum is probably

monochromatic; if admixture of any other color sensation were present, the curve would rise or fall instead of remaining horizontal. The same apparently applies to the violet end of the spectrum, though, owing to the small luminosity, exact measures of it are less certain. The experiments show that the rays having the wave-length of about λ 4770 are the last perceived. The shift in the position of maximum resistance to about λ 4510, as shown in Table II, is due to the fact that equal luminosities of each color have been considered as being reduced.

Some interesting experiments were carried out by placing slits in different parts of the spectrum, and forming a mixture of light on the ground glass of the apparatus. An intense D light mixed with a faint light near F formed a color patch, and this mixed light was extinguished and found to require 9° of aperture of the sector. The D light was then shielded and the single ray of blue-green light was extinguished, when it was found that the same aperture was required to extinguish this beam alone. Red and green and various other mixtures were tried, all showing that in the extinction of light the green-blue light was the last visible, and was equivalent to extinguishing that light alone, although it might be mixed with very much brighter light in the red or yellow. In the blue the conditions somewhat change, as will be seen in the diagram, but if slits of equal aperture were used the same results were obtained.

The diagram shows that in the spectroscopy of feeble light the rays in the blue and green are the first to be perceived, and that rays of far greater intensity in the yellow and red may exist without exciting the sense of light. This may account for some of the varied results recorded in eye spectroscopic observations of sources of feeble luminosity, in which the yellow and red lines are absent.

In extinguishing white light, the fact of the total extinction of the blue-green light is of importance.

It is not the *light* at that particular wave-length which disappears last, but some one *sensation* which is principally existent at that point, but which extends over a great portion of the spectrum which has to be extinguished. For instance, in extinguishing the light from the reflected beam of the electric light already alluded to, it was found that the light illuminating the ground glass was 720 times brighter than that reaching the screen. To extinguish 0.014 of the light from an amyl lamp on the ground glass the sector had to be closed to 21, that is the light of one amyl lamp luminosity, falling on the screen at 1 foot

distance, had to be reduced to $\frac{14}{1000} \times \frac{1}{720} \times \frac{21}{180}$ or $\frac{1}{441,000}$ of the original light. Had the luminosity of the unit of luminosity been due entirely to the color at λ 4776, it would have to be reduced to about $\frac{1}{900000}$ of its luminosity before it became invisible. Thus the electric light gives about half the sensation of this light that the monochromatic light of that color and luminosity would give, and hence we may conclude that about half the luminosity of the white light is due to this sensation, of course distributed unequally through its spectrum. This is a very close approach to the area of the green sensation curve of the spectrum when the luminosity is taken into account.

It would thus appear that by studying the extinction curves it may be possible to approximate to the three positions in the spectrum which the colors giving the nearest approach to the three fundamental sensations on the Young-Helmholtz theory occupy.

THE ASTRONOMICAL EXHIBIT AT THE WORLD'S COLUMBIAN EXPOSITION.

The four hundredth anniversary of the discovery of America by Columbus is to be fittingly celebrated at Chicago in 1893. In buildings which themselves sufficiently emphasize the progress of American architectural skill, the exhibits of the world will be so grouped as to render evident to the visitor the gradual development and the present condition of every art, science and industry. Only those who have recently visited the grounds of the Exposition, and watched the daily progress achieved by an army of nearly five thousand workmen, can have any adequate idea of the exalted standard of excellence which the directors have in view. Some of the buildings are practically completed, and it is already possible to faintly picture the Venice-like beauty which the waters of Lake Michigan and the winding lagoons will lend to the scene. But it is not with the evidence of material progress that we are now dealing. It is of more interest to learn that a space nearly 800 feet long and 300 feet wide has been set apart in the largest and best situated building on the grounds for the use of the Department of Liberal Arts, and in this space the astronomical exhibit will naturally be found.

The scope and nature of this exhibit will largely depend upon the liberality with which astronomers and instrument makers

respond to the call for a full and complete display. Advices already received from Warner & Swasey, J. A. Brashear and Alvan Clark indicate that there will be no lack of instruments of the highest class. It is hoped that there will be at least one refracting telescope of fully 20 inches aperture, and among a number of smaller refractors it is probable that two will exceed an aperture of 12 inches. Reflectors will be shown in all sizes, while the mere fact that Brashear will exhibit is sufficient guarantee that spectroscopes of all kinds, gratings, prisms, flat surfaces, etc., will not be lacking. Two large domes have been arranged for, and a complete working model of the Lick Observatory is now being made. As many apparatus makers are yet to be heard from, the outlook in this direction is most encouraging.

The great advances in astronomy and spectroscopy which have resulted from the application of photography should be fully illustrated. At the Lick Observatory a large number of transparencies on glass, eight by ten inches in size, are being prepared from negatives of the Moon, Jupiter, etc., and the remarkable success of the Henry Draper Memorial will no doubt be exemplified by a large collection of photographs of the stars and stellar spectra from the Harvard College Observatory. It is to be hoped that Professor Rowland will send many specimens from the extensive series of photographs of solar and metallic spectra on which he is now engaged.

It is also proposed to include in the exhibit a collection of photographs of all telescopes in the United States of six inches aperture and upwards, together with all important spectroscopes and special instruments employed in astronomical or spectroscopic investigation. It is desirable that the photographs be, so far as possible, of the uniform size of eight by ten inches. They may be either glass transparencies, or *unmounted* paper prints. The latter will be properly mounted by those who have charge of their installation.

Finally, a large collection of American astronomical publications is desired. These will include complete sets of the publications of observatories and societies; periodicals; books and papers on astronomy and spectroscopy, etc.

It will be noticed that only American exhibits are here called for. The arrangements of the 52 foreign countries which have officially announced their intention of participating in the Exposition are such that the exhibits will be grouped by nations, rather than by subjects. While this natural system may possess some disadvantages as compared with a rigid classification by

subjects, it will at the same time have the corresponding advantage of stimulating national pride. If, as we hope, every foreign country will give as much attention to an astronomical as to an industrial exhibit, the United States will need to look to her laurels. An *adequate* representation of our part in the progress of astronomy would undoubtedly substantiate our claim to an important position among the nations engaged in the advancement of research.

The pages of ASTRONOMY AND ASTRO-PHYSICS are open to anyone who wishes to express his ideas on the subject of an astronomical exhibit, and correspondence and suggestions, for publication or otherwise, are requested. The editor of ASTRO-PHYSICS is secretary of a committee on the Columbian Exposition appointed by the Astronomical Society of the Pacific, and is authorized to act in their behalf. Applications for space are desired as soon as possible, and should be addressed to Director-General George R. Davis, World's Columbian Exposition, Chicago. Information in regard to the installation of the astronomical exhibit may be obtained from Dr. Selim H. Peabody, Chief of the Department of Liberal Arts. It may be added that the foregoing has been published with his approval.

A NEW PHOTOGRAPHIC PHOTOMETER FOR DETERMINING STAR MAGNITUDES.*

W. E. WILSON.

I would like to bring before the notice of the Society the design of an instrument which I think will be of use in stellar photography, and especially in determining photographic magnitude of stars.

The instrument consists of a photographic plate and holder (6½ in. x 1 in.) moving in a slide in the direction of its greatest length. A spiral spring tends to pull the holder to one end of the slide, and a simple electro-magnetic escapement each time the magnet is excited allows the spring to advance the plate and holder $\frac{1}{10}$ inch. The entire apparatus screws into the eye-end of a photographic telescope.

A star whose magnitude is to be determined is focussed close to the end of the photo plate, and an exposure of say 100^s given. The magnet is then excited for a moment by the current from a

* *Monthly Notices*, January, 1892.

contact-maker, driven by a clock; the plate moves forward suddenly $\frac{1}{10}$ inch, and a second exposure is given, which lasts only 63^s. Again the plate moves forward to give a third exposure of $39^{s}\cdot 8$, and the exposures are thus continued in the above ratio until they are reduced to 1^s. The telescope is then set on a standard star, such as *Polaris*. The holder is moved back to its original position, and *Polaris* is placed $\frac{1}{10}$ inch below the first exposure of star No. 1. The same series of exposures are then given, and the plate developed. The result will be like this:—

Polaris =

Star No. 1 =

The relative number of images of the two stars will give their magnitudes to 0.5. The times of exposures will vary as the number whose log. is 0.2, but there is no reason why they should not be made to give 0.1 magnitudes.

The contacts are made by a wooden disc, revolving uniformly by the driving clock of the equatorial. On its edge are brass pins, which are placed so as to pass under a wiper at the correct intervals. The entire process is automatic once the star is set in its right place. Each plate will hold ten sets of exposures.

The instrument will also be of use for determining the actinic value of the sky before taking a stellar photograph. In this case, by taking a series of *Polaris*, and finding thus at what exposure it fails to record itself, the exposure necessary to record a star of another magnitude will be known.

Also, to determine the value of wire screens in front of the O. G., a series can be taken with and without the screen and the necessary value found.

I hope to exhibit some negatives taken with the instrument shortly before the Society.

1892 January 3.

NOTE ON THE SPECTRUM OF THE LARGE SUN-SPOT GROUP OF FEBRUARY, 1892.*

HENRY CREW.

This group, during the time the weather permitted it to be seen here, consisted essentially of two large umbræ, surrounded by a number of small spots. The outlines of these two larger umbræ

* Communicated by the author.

PLATE XII.

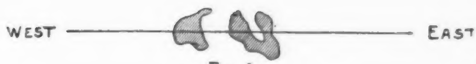


Fig. 1

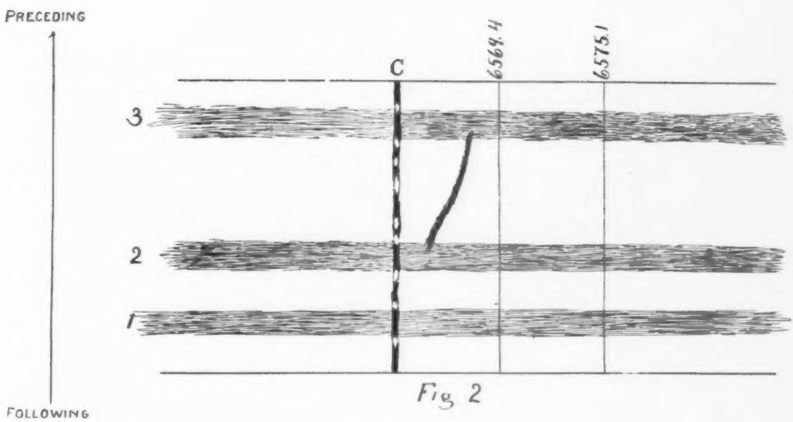


Fig. 2

Plate accompanying Dr. Henry Crew's paper on the Spectrum of the Large Sun-Spot Group of February, 1892.

are shown in Plate XII, *Fig. 1*, from which it will be seen that, when the slit of the spectroscope was placed across them in an east and west direction, and in the position indicated by the straight line in the figure, the spectrum presented the appearance of *three* umbræ, owing to the cleft in the spot to the right.

I examined this spot first on the 9th of February, with especial reference to some of the lines assigned to *coronium* in Professor Rowland's unpublished map of the spectra of the elements. But they appeared not to be affected in the slightest.

On February 10th, nothing was noticed, during half an hour's observation, that would distinguish the spectrum of this spot from that of what Langley has called the "typical Sun-spot."

C was brilliantly reversed in both nuclei, and showed a moderate amount of motion.

D_3 was bright in both nuclei and in the penumbræ. The lines b_1, b_2 and b_4, were disturbed and reversed a good part of the time, etc. But on the 11th, the region between the two umbræ presented the following phenomenon which, to the writer, at least, is entirely new. I was observing the spot in the third order of a Rowland 14438-line grating, attached to the 12-inch equatorial. The slit was placed in an east and west direction, in the position of the straight line in Plate XII, *Fig. 1*. The appearance presented in the neighborhood of the C line is shown in *Fig. 2*, which is copied directly from my observing book. Following the figure, I find these notes.

"C reversed in all the penumbræ and, at numerous points along the space between 2 and 3, very brilliant. This appearance remained practically unchanged for an hour."

"At 9^h 50^m, I observed a new dark line, very broad, extending in a diagonal direction between adjoining edges of spots 2 and 3.

Watched it for a full half hour, thinking it might be a part of C. I turned to F, to see if that was affected in a similar manner, but could not find any trace of the new dark line there."

"It appears the same in the second, third and fourth orders of the grating."

Plate XII, *Fig. 2*, gives a very fair idea of the phenomenon. The line was quite sharp and of nearly uniform width throughout its length. The point, at which the line appeared to leave umbra No. 2, was at $\lambda = 6566.0$; from here it ran across the interlying portion of the photosphere, and joined umbra No. 1 at $\lambda = 6567.5$. These figures may be out as much as two units in the first decimal place; not more, I should think, for I had Rowland's map before me. The difference of wave-length between

the two ends thus corresponds to a velocity of between forty and fifty miles per second: in which direction, one cannot say without knowing the place of the line. On Rowland's map there are two, possibly three, lines visible between C and the iron line at $\lambda =$ 6569.3; but there is too much motion in the new line to say whether it corresponds to either of these. Hasselberg has a nitrogen line at 6566.47.

This phenomenon appears to be just the reverse of what ordinarily happens *viz.*, the line, instead of showing strong absorption in the umbræ and penumbræ, is not visible there at all; while in the regions between, the absorption is very striking.

Looking for this appearance again in the afternoon of the same day, I found no certain trace of it.

On the following day, (February 12th), the spot was re-examined; but no relic of the dark line was seen, though twenty-nine other lines, between C and *w. l.* 5727.9, were observed as thickened in the spot spectra.

Lick Observatory, 4th of March, 1892.

SPECTROSCOPIC OBSERVATIONS OF THE GREAT SUN-SPOT GROUP OF FEBRUARY, 1892.

GEORGE E. HALE.

This spot group was first seen at the Kenwood Observatory on the morning of February 4, and from that time it was observed as frequently as possible during its entire transit. The observations included: (1) photographs of the Sun at the focus of the 12-inch equatorial for position and form of the group; (2) photographs of the spot group and surrounding faculæ, made with the "spectroheliograph";* (3) photographs of the spectra of various members of the group; (4) visual observations with the helioscope; (5) visual observations with the spectroscope. In the present paper we shall confine ourselves mainly to observations under (3) and (5).

On Feb. 4 an eruptive prominence was observed on the limb where the spot group had entered the visible hemisphere, and an excellent photograph of it was made with the spectroheliograph. On Feb. 9 bright reversals were seen in both C and F over the largest umbra. With a wide slit the form of the reversed region

* The spectroscope with slits moved by a clepsydra and hydraulic accumulator, referred to in my previous papers on solar prominence photography.

could be easily observed in C. The bright light of the photosphere was too dazzling to allow of a slit wide enough to include the entire reversed region, but by moving the instrument about, a sketch was easily made at $10^h\ 47^m$ (Chicago M. T.). At this time there was no evidence of motion in the line of sight, and when observed a few minutes later the D lines were not seen to be reversed. No trace of D_3, dark or bright, could be made out. A great number of lines in the solar spectrum were widened in the umbræ, but in this and the later observations the press of other work did not leave time to record them. Between $11^h\ 10^m$ and $11^h\ 28^m$ ten photographs were made of the spot spectrum, the slit crossing the largest nucleus. The fourth order of a 14438-line grating was employed. As is usual in spots, both H and K are reversed, but none of the ultra-violet hydrogen lines appear in the negative, if we except hydrogen ϵ (near H), of which there is a slight suggestion. As I found was usually the case in photographing the spectra of faculæ last December, H and K are *doubly* reversed, a dark line appearing in the center of the bright reversal. In the spot now in question the double reversal is most easily seen in the penumbra, where the bright line is widest. In the center of the spot the bright line is much narrower, but in a sharp negative the double reversal can be seen very close to the narrowest part of the line. There are portions of the line, in some cases comparatively wide, where no trace of double reversal can be made out. As I have previously found to be true in prominences, K is stronger than H, and the double reversals are also more pronounced in the former line.

At $2^h\ 40^m$ P. M., no particular change in the spectrum was noticed. The form of the reversed region could be seen even better than at the time of the morning observation, and a drawing of it was made. On comparing this drawing with a photograph of the faculæ made fifteen minutes before, it is found that the faculæ in the midst of the spot group correspond so closely in form with the reversed region as observed in the C line that there can be no doubt as to their identity.

I reserve for a future paper a discussion of the question of observing prominences projected on the Sun's disc. In the present instance the form shown in the photograph seems to be in all probability faculous, for the exposure was the same that is always given for faculæ, and this is insufficient for prominences of ordinary brightness on the limb. At the same time there is nothing to contradict the assumption that a very brilliant prominence was seen in the C line, and photographed in K. When I

discovered that H and K are reversed in the faculæ*, the resemblance between prominences and faculæ on the disc was more clearly brought out than ever, for the reversals in both are thus shown to be the same. The fact that the spectroheliograph allows photographs to be made of spots, prominences, faculæ, and the bright forms near spots (whatever they may be) as well, will enable me, I trust, to learn something more as to the relations existing between these various phenomena.†

Clouds prevented all but the regular photographic work on Feb. 10 and 11. As Dr. Crew's observation of a peculiar absorption line near C was made on the latter date (see page 308), I have examined the photographs then secured here. Exposures were made at the focus of the 12-inch at $10^h\ 10^m$, $10^h\ 20^m$ A. M., and $2^h\ 6^m$, $2^h\ 30^m$ P. M. None of these show anything unusual, though the spots are well defined in all the plates. Allowing for the difference in time between Mount Hamilton and Chicago, however, it is evident that none of the exposures happened to be made very near the time of Dr. Crew's observation. Photographs of the spots and faculæ were obtained with the spectroheliograph at $10^h\ 55^m$, $10^h\ 59^m$, $11^h\ 5^m$, $11^h\ 12^m$ and $11^h\ 15^m$ A. M. on the same day. Whether the phenomenon in question produced any effect which such photographs would have shown cannot therefore be answered, as no exposures were made at the proper time.

On Feb. 12 the spot spectrum was examined at 12^h M., and D_3 was once suspected as a dark line. C was considerably distorted in the largest umbra, but not so much so as in the last following member of the spot group, where at one point simultaneous displacements toward the red and violet were noticed. Reversals of C were numerous in the group, the brightest being seen over the largest umbra. On referring to plates made at this time with the spectroheliograph, the brightest reversed region is found to be south of the largest umbra, and the central one of its three branching arms passes between the two principal umbræ. These photographs of the spectrum confirm the results obtained Feb. 9, as to the double reversal of H and K in the penumbræ, and the

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* See ASTRONOMY AND ASTRO-PHYSICS, Feb. 1892, p. 159 and March, 1892' Note on Progress in Solar Photography at Kenwood Observatory.

† Naturally the spectroheliograph does not give sharp and well-defined images of *spots*, for the second slit cannot be made sufficiently narrow in practice. The spots are also partly or wholly covered by the reversed regions, and it is these latter which the spectroheliograph is specially designed to record. The negatives give a very fair idea, however, of the position and general form of spots, and are studied in connection with spot photographs taken by the ordinary method.

PLATE XIII.

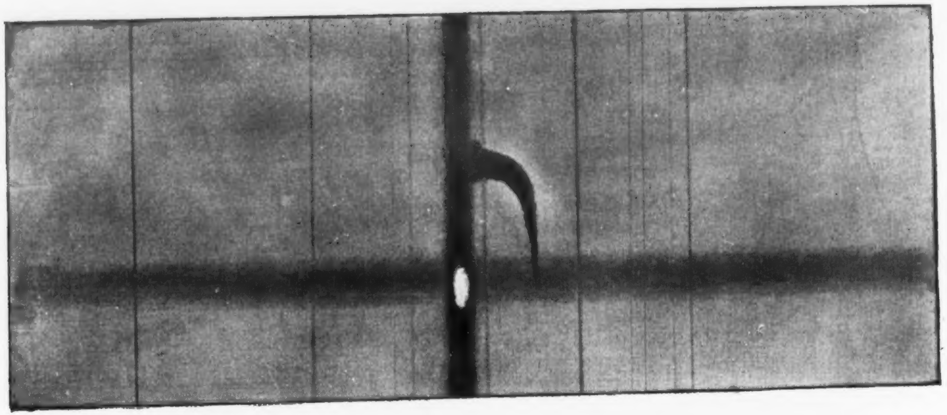

Plate accompanying Professor Hale's paper on Spectroscopic Observations of the Great Sun-Spot of February, 1892.

narrowing of the bright lines towards the center of the umbra. As the bright lines narrow down in the umbra to about the width of the central dark line in the penumbra, it is evident that double reversal could hardly occur in the umbra without practically destroying both lines. Two facts of importance should be mentioned here: both point to a difference of some kind between the condition of the vapors from which C, a hydrogen line, and H and K, calcium lines, are emitted: (1) While C was distorted in the spot region H and K were perfectly straight, and gave not the least indication of motion in the line of sight. Moreover, I do not recall a single instance in which the H and K lines in spots have shown any distortion, while it is well known that C is almost always twisted and bent under like circumstances. (2) Double reversals are rarely (if ever) observed in the C line, while they are almost invariable in H and K over spot penumbræ and on the disc. This fact is perhaps not surprising, but the absence of motion of the calcium in the neighborhood of spots is not readily explainable.

Photographs of faculæ were made with the spectroheliograph on Feb. 13 at 10^{h} 45^{m}, 10^{h} 47^{m} A. M., and 2^{h} 58^{m}, 2^{h} 49^{m}, 3^{h} 6^{m}, 4^{h} 16^{m}, P. M. Between 10^{h} 54^{m} and 11^{h} 34^{m} A. M., six photographs were obtained of the spectra of various regions in the spot group, using the fourth order of the grating as before. The bright H and K lines extend entirely across the spots, narrower in the umbra than in the penumbra. In one spot the bright lines almost completely disappear at the center of the umbra, where they narrow down to about the width of the central dark line of the double reversal. But the most interesting thing brought out in some of these photographs is the probable presence of the line hydrogen ϵ (near H). In common with Professor Young, I have been perplexed at the non-appearance of this line in spots, for it so constantly accompanies H in prominences. It appears as a very faint line in these photographs, following H across spots and on to the surrounding photosphere. No other ultra-violet hydrogen lines are present, and as yet not the least trace of any of them has been detected in spots.

Clouds prevented further work until 3^{h} 45^{m} P. M., when considerable distortion was noticed in the C line of the second order. The figure in Plate XIII has been copied from a note-book sketch made at this time.* No great degree of accuracy can be claimed for this sketch, as the amount of displacement is only estimated, but it may serve for comparison with Dr. Crew's drawing in

* The scale of the figure is about that of Rowland's map.

Plate XII. The position of the narrow slit was such that it lay across the smaller of the two large umbræ; if the larger were shown on the plate it would appear about half way between the two lines to the right at λ 6569.4 and λ 6575.1, and the same distance below the horizontal absorption band, supposing the C line to represent the slit. As in Dr. Crew's observation, the distorted absorption line was outside of the umbra. It lasted only a few minutes, and I did not have sufficient time to examine it as I might have wished. C was reversed in the umbra as shown, and also in other points not given in the sketch. In the larger umbra a reversal of C was distorted toward the violet.

It would seem that the absorption line noted by Dr. Crew may be due to a motion of recession of the whole mass of absorbing hydrogen, the velocity increasing from one end to the other. It is strange, however, that F did not show similar evidence of motion.

The last spectroscopic observations of the spot group were made here on Feb. 15. C indicated some motion, and was reversed in many places. With a wide slit the reversed region could be fairly well seen. At a point where a radius through the group met the limb a prominence of some size was noticed, but no reversal could be traced from it to the spots. Clouds unfortunately prevented observations of the passage around the western limb.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, March 14, 1892.

NEW RESEARCHES ON THE SOLAR ATMOSPHERE.*

H. DESLANDRES.

In a former note (*Comptes rendus*, August, 1891; also ASTRONOMY AND ASTRO-PHYSICS, January, 1892), I have described my investigations made by means of photography on the radiation of the solar atmosphere in a hitherto unexplored region, comprising the blue, violet and ultra-violet to λ 380. I have continued this study in the neighboring region of the invisible ultra-violet as far as λ 350.

Apparatus.—But, in this new region, the radiations are strongly absorbed by ordinary optical glass, and it has been necessary to change the original apparatus. For the projection of the solar

* Communicated by the author. (Presented to the *Academie des Sciences* February 8, 1892).

image I have employed the Foucault siderostat and an 8-inch silvered concave mirror. The prism spectroscope has also been replaced by a spectroscope with a Rowland grating and quartz lenses.

Results.—Each photograph gives the spectrum of the Sun's limb from λ 410 to λ 350, and shows all the chromosphere lines in this extended region, the arrangement adopted assuring the simultaneous focusing of all the rays on the slit.*

In several prominences in the second quarter of 1891 I red-iscovered the series of ultra-violet hydrogen lines observed for the first time by Mr. Huggins in the white stars. I have obtained as many as eight successive bright lines,† all narrow and sharp,‡ and the last two of the series could undoubtedly be obtained at a high mountain station. Thus the Sun, which is a yellow star, exhibits in certain parts of its atmosphere the characteristic radiation of the white stars. This result is important, for it confirms our present ideas on the evolution of the stars.

I have also obtained the line slightly less refrangible than α_1 (λ 388) of hydrogen, which was first discovered by Mr. Hale, and recently contested by Professor Young. But this line, always fainter than or at most equal to the line $H\alpha_1$, is not often present. The only permanent lines which I have observed in this region are those of hydrogen.

With this apparatus, which is of greater dispersive power than the former one, I have also photographed the spectra of spots and faculæ. The H and K lines of calcium often appear bright, and they are always longer and more intense than the lines of hydrogen;§ moreover, the great width of the dark bands which form their background is particularly favorable for the study of displacements and radial velocities. These photographs are thus suited, in a certain measure, to the regular study of the movements of the solar atmosphere in the part which is projected on the disc. The photographic spectroscope, movable around an axis, as described in the preceding note, will allow the forms and velocities of the incandescent masses at the surface of the Sun to be registered, not only in the annular region which surrounds the disc, but in the entire hemisphere turned toward the Earth.

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* These photographs have been obtained with the aid of my assistant, M. Mittau.

† Mr. Hale has already announced that he has found five of these lines; Professor Young has obtained four.

‡ As is well-known, these ultra-violet hydrogen lines are missing in the spectrum of the disc, or appear very much widened.

§ These bright lines often have also a reversal in the center.

THE SUN-SPOTS, THE MAGNETIC STORM, AND THE AURORA.*

The abnormal condition of the Sun during the period 1892, Feb. 5-17, owing to the presence of a large group of Sun-spots, attracted the attention of all solar observers. With such tremendous disturbances in progress in the solar photosphere, some disturbance of the magnetic condition of the Earth was to be expected, and the magnetic storm of Feb. 13-14 was characterized by an intensity quite in keeping with the solar disturbance with which it was connected. The magnetic storm, which seriously disturbed the telegraph and telephone services throughout the world, was attended by one of the most brilliant auroral displays of recent years.

The group of Sun-spots to which these terrestrial disturbances are directly attributed appeared on the east limb of the Sun on 1892, Feb. 5, reached the central meridian on Feb. 11, and passed round the west limb on Feb. 17.

The total spotted area, measured on the photographs taken at Greenwich on Feb. 13, when the group reached its maximum, was no less than $\frac{1}{350}$ of the Sun's visible hemisphere. At Greenwich the area of spots is measured in millionths of the Sun's visible hemisphere, and this extensive group had an area of 2850 millionths, corresponding to 3360 millions of square miles. The center of the group was then at 260° long., and in latitude — 23°.

The group was a broad band extending over 22° of longitude in length and 10° of latitude in width, corresponding roughly to a greatest length of 150,000 miles and a width of 75,000 miles.

The large central spot of the group was 15° in length in longitude and 8° in width in latitude. The spot-group is the largest ever photographed at Greenwich, and is the largest which has appeared on the Sun since 1873. The large group of 1882, Nov. 18, was 2425 millionths of the Sun's visible hemisphere in area.

At Kew the magnetic disturbance commenced at about 5:45 A. M., on Feb. 13, the easterly declination slightly increasing until about 5:40 P. M., while both horizontal and vertical forces increased in intensity, especially between 4 and 6 P. M. They diminished after 10 P. M., but the changes became very rapid from 12 o'clock midnight to 2 A. M. (Feb. 14), the declination proceeding to its extreme westerly position. The disturbance gradually diminished and died out about 4 P. M. Feb. 14. So rapid were

* *Observatory*, March 1892.

the changes of force, and so great the extent of the vibrations of the free needles (over 2° in declination), that the Kew magnetometers could not record them.

At Potsdam the disturbance commenced on Feb. 13, about 6:30 P. M. (Berlin mean time), and enormous fluctuations of the needle were noticed. Changes of 2° in 2 minutes of time are recorded, and vibrations of over 3° were observed.

The records of the Greenwich magnetic instruments are fully dealt with in the notes of Mr. Ellis, published in this number.

The aurora of 1892, Feb. 14, was observed at Greenwich at $0^h\ 35^m$ to $0^h\ 45^m$ as a brilliant patch of crimson light extending from the N. N. W. to N., with streamers of a whitish color rising to an altitude of 50° or more, and converging to the right. Between $0^h\ 45^m$ and $0^h\ 50^m$ the crimson glow became more intense, afterwards dying away until at $0^h\ 55^m$ it disappeared, the streamers being visible to the last, but fluctuating in brightness. Light clouds formed to the North at $0^h\ 55^m$, and at $1^h\ 15^m$ the sky was completely overcast.

At Ealing the aurora was first noticed at $0^h\ 30^m$ as a faint crimson light in the N. N. W., which rapidly increased in intensity. Streamers of a yellowish-white color were estimated to extend to an altitude of 60°, converging towards the north. Clouds immediately commenced to form to the N. N. W., and the contrast between the brilliant white clouds in the moonlight, the bright crimson sky, and the slightly yellowish streamers was very striking.

Attempts were made to observe the spectrum of the aurora with the star-spectroscopes used for the 5-foot reflector, but, except a faint brightening in the green, no details could be made out, owing to the bright moonlight.

The crimson glow at 0:50 A. M. extended round from N. W. N. to N. N. E., and a faint streamer arose from N. N. E. towards the north to an altitude of about 40°. The brightness of the streamers varied considerably, but they were visible until the sky was completely overcast at 1:10 A. M. The crimson glow was fainter after 1 A. M., but was visible through breaks until the clouds covered the sky.

MAGNETIC PERTURBATIONS OF FEBRUARY 13 AND 14, 1892.*

M. MOUREAUX.

An extraordinary magnetic perturbation, such as we have not observed for ten years, and even surpassing that of November, 1882, in intensity, was registered on the magnetograph of the Saint-Maur Observatory on February 13 and 14. It suddenly commenced on the 13th, about $5^h 42^m$ A. M., by a simultaneous rise in the declination and horizontal component, and a corresponding fall in the vertical component. The oscillations of the first two elements were rapid, and of considerable amplitude all day on the 13th; after noon, the vertical component increased progressively, and passed a considerable maximum between 4^h and 6^h P. M. At this same moment the declination reached a minimum, while the horizontal component exhibited nothing particularly remarkable.

The most important phase of the perturbation occurred between 11^h P. M. and 2^h A. M. The absolute maximum of declination was reached between midnight and 1^h, while the two components passed an exceptional minimum: the vertical component about 1^h, and the horizontal component between 1^h and 2^h A. M. The deflections were so great that the three images went out of the field, a circumstance which prevents the accurate determination of the extreme values, as well as the exact time when these values were attained.

After 3^h A. M., the oscillations, though still marked, were of somewhat smaller extent, and after 6^h 30^m the three magnets were affected by vibratory movements until 9^h, at which time the sheet of sensitive paper had to be renewed. The perturbation ceased at about 5^h P. M. on the 14th. The total deflection for declination was more than $1° 25'$; the horizontal and vertical components varied more than $\frac{1}{37}$ and $\frac{1}{88}$ of their normal values respectively.

According to the curves of the recording instruments at Perpignan, Lyons and Nantes, communicated by Dr. Fines, M. Andre and M. Laroque, the phenomenon commenced at the same instant, and the variations were so faithfully reproduced at the four stations that, with the exception of a few changes of intensity in certain details, the tracings of the four instruments agree exactly, like copies of a single drawing.

This perturbation is sharply distinguished from all others ob-

* Translated from *Comptes rendus* (Paris), Feb. 15, 1892.

served here by the excessive variations in the vertical component. A very important group of Sun-spots, which first appeared on February 5, and which could be seen on the 12th with the naked eye, was passing near the center of the Sun's apparent disc on this same day. A very brilliant aurora borealis was seen at New York on the night of February 13-14.

THE REDUCTION OF SPECTROSCOPIC OBSERVATIONS OF MOTIONS IN THE LINE OF SIGHT.*

W. W. CAMPBELL.

The reduction of spectroscopic observations of motions in the line of sight is made exceedingly simple by the use of suitable tables. I herewith publish my tables with an explanation of their construction and use, in the hope that other observers will find them convenient. The results are expressed in English miles per mean solar second. They are convertible into German geographical miles by dividing them by 4.6038; or into kilometres by multiplying them by 1.6093. The remarkable accuracy of recent spectroscopic observations requires that the corrections be applied to the nearest tenth of a mile per second. The still greater accuracy which may reasonably be expected in the future will require that they be applied to the hundredth of a mile per second, and such is the limit of precision adopted in these tables. While the values of the variable quantities (e and Π only) have been taken for the epoch 1895, yet they vary so slowly that the errors do not amount to 0.01 miles per second for nearly thirty years.

According to Doppler's principle, the motion of a star in the direction of the observer, or from the observer, is indicated by a displacement of the lines in its spectrum from their normal positions; toward the red end if the star is receding from him, and toward the violet end if it is approaching him. The observation, whether visual or photographic, consists in the measurement of this displacement, which is generally expressed in terms of the unit of wave-length in Angström's scale. This unit is the *tenth-metre*, and denotes a change of one ten-millionth of a millimetre in the wave-length. A table giving the velocities of the star corresponding to a displacement of one tenth-metre in the different parts of the spectrum will enable us to obtain quickly the velocity corresponding to any observed displacement.

* Communicated by the author.

Let λ be the wave-length, expressed in tenth-metres of the line whose displacement is measured; V_s the velocity of a star in English miles per second corresponding to a displacement of one tenth-metre; v_s the velocity corresponding to any measured displacement $\Delta\lambda$; and let the velocity of light be assumed as 186,330 miles per second. Then

$$V_s = \frac{186{,}330}{\lambda} \tag{1}$$

and

$$v_s = V_s \,.\, \Delta\lambda. \tag{2}$$

$\Delta\lambda$ and therefore v_s are considered positive when the wave-length is increased, and denote a recession of the star; they are considered negative when the wave-length is decreased, and denote an approach of the star. Table I is constructed from equation (1), and gives the values of V_s for the principal Fraunhofer and other lines, and for each hundred units of wave-length in the photographic part of the spectrum.

The observed velocity is due both to the motion of the star and of the observer. The latter is made up of four components, all of which must be eliminated from the observation before the component of the star's velocity, with reference to the sidereal system, can be determined. The four components arise from

1. The rotation of the Earth on its axis. The elements of this diurnal component are well known, and it can be eliminated completely from the observed results.

2. The revolution of the Earth around the common center of gravity of the Earth and Moon. This monthly component is small and readily allowed for.

3. The revolution of the Earth around the Sun. The *form* of the Earth's orbit is well known, but there is at present an uncertainty of from one-half to three-fourths of one per cent in the assumed value of the solar parallax, or in the absolute value of the semi-major axis of the Earth's ellipse; which introduces a corresponding uncertainty in the Earth's orbital velocity of from 0.09 to 0.14 miles per second. By assuming the Earth's mean distance from the Sun to be 92,500,000 miles, which corresponds to a solar parallax of $8''.838$, it is probable that the resulting orbital velocities will not be in error by more than 0.1 miles per second. There is reason to hope that the probable errors of spectroscopic observations will soon reach this low limit, in which case the problem will be reversed and the spectroscope will be used to *measure* the Earth's orbital motion and thus to determine the solar parallax.

4. The motion of the solar system as a whole. At present we have not sufficient data for estimating its direction and velocity, and this component can not now be eliminated from the observed velocities of the stars. Several astronomers are engaged in measuring the velocities of the brighter stars. When the velocities of several hundred stars distributed fairly uniformly over the celestial sphere have been well determined, we shall be able to obtain a fairly accurate knowledge of the motion of the solar system. The corrections for the solar motion can then be applied to the observations of the individual stars, and we shall be able to obtain their velocities in the line of sight with reference to our sidereal system.

When the corrections for the first three motions are applied the observations are said to be reduced to the Sun.

Let e = the eccentricity of the Earth's orbit,
= 0.016752 for 1895,
a = the semi-major axis of the Earth's orbit,
= 92,500,000 English miles,
$90^\circ - i$ = the angle which the tangent to the Earth's orbit makes with the radius vector drawn to the point of tangency,
T = the number of mean solar seconds in a sidereal year,
= 31,558,149,
Π = the longitude of the Sun at perigee,
= $281^\circ\ 8'.0$ for 1895,
$\odot$ = the Sun's longitude at the time of observation,
☾ = the Moon's longitude at the time of observation,
λ = the longitude of the star observed,
β = the latitude of the star observed,
t = the hour angle of the star observed,
δ = the declination of the star observed,
φ = the latitude of the observer,
V_a = the Earth's velocity in miles per second in its orbit,
v_a = the correction to the observed velocity of the star for this annual motion,
V_m = the Earth's velocity in miles per second due to its revolution about the center of gravity of the Earth and Moon,
v_m = the correction to the observed velocity of the star for this monthly motion,
V_d = the velocity in miles per second of a point on the Earth's equator due to the diurnal rotation, and
v_d = the correction to the observed velocity of the star for this daily motion.

The values of i and V_a are given by*

$$\tan i = \frac{e \sin(\odot - \Pi)}{1 + e\cos(\odot - \Pi)} \tag{3}$$

and

$$V_a = \frac{a}{\sqrt{1-e^2}} \cdot \frac{2\Pi}{T} \cdot [1 + e\cos(\odot - \Pi)] \sec i. \tag{4}$$

When the Sun's longitude is $\odot$ the Earth is approaching the point of the ecliptic whose longitude is $\odot + 270° - i$, with a velocity V_a. Projecting this motion upon the line joining the observer and the star (λ, β) we obtain

$$v_a = - V_a \sin(\lambda - \odot + i)\cos\beta. \tag{5}$$

In Table II the values of V_a and i are tabulated as functions of $\odot$; so that to find the value of the correction v_a it is only necessary to find $\odot$ in the Nautical Almanac for the instant of observation, take the values of V_a and i corresponding to this value of $\odot$ from Table II, and substitute them in equation (5). The maximum error introduced by neglecting i is 0.31 miles per second. If it is desired to use a value of the solar parallax different from that employed here, it is only necessary to multiply the values of V_a given by Table II, by a constant factor.

The value of the lunar correction v_m can usually be neglected. But its maximum value is nearly 0.01 miles per second, and the degree of precision adopted for these tables requires that it should be considered here. It is not necessary, however, to take into account the ellipticity of the orbit and its inclination to the ecliptic. The average value of V_m is nearly 0.01 miles per second, and the motion is toward the point of the ecliptic whose longitude is ☾ + 270°. Therefore, projecting this motion upon the line drawn to the star (λ, β), we have

$$v_m = - V_m \sin(\lambda - ☾) \cos\beta = -0.01 \sin(\lambda - ☾)\cos\beta. \tag{6}$$

Owing to the diurnal rotation the observer is constantly approaching the east point of the horizon, with a velocity

$$V_d \cos\varphi = 0.29 \cos\varphi.$$

Projecting this motion upon the line drawn to the star (t, δ), we have

$$v_d = - V_d \sin t \cos\delta \cos\varphi = -0.29 \sin t \cos\delta \cos\varphi. \tag{7}$$

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* Equations similar to (3) and (4) are derived in *Chauvenet's Sph. and Prac. Astr.*, vol. I, § 391.

The values of this correction for the latitude of Mt. Hamilton (37° $20'$) are tabulated in Table III with the arguments t and δ. The corresponding corrections at any other latitude φ' can be obtained from these by multiplying them by $\frac{\cos\varphi'}{\cos\varphi}$. v_d is negative if the star is observed west of the meridian, positive if the star is observed east of the meridian.

Example. At Mt. Hamilton, 1891, Nov. 24, 9^h 35^m Pacific standard time, measures of the position of D_2 in the third spectrum of Aldebaran showed a displacement of 0.908 tenth-metres toward the red. Required the velocity of the star with reference to the solar system.

For Aldebaran we have

$$\alpha = 4^h\ 29^m\ 40^s, \qquad \delta = +16^\circ\ 17'.4,$$
$$\lambda = 68^\circ\ 16'.0, \qquad \beta = -\ \ 5^\circ\ 28'.5.$$

The solution of (2) gives

$$\begin{aligned} \log V_s &= \log 31.63 \ = 1.5001 \\ \log \Delta\lambda &= \log\ \ 0.908 = 9.9581 \\ \log v_s &= \qquad\qquad\quad 1.4582 \\ v_s &= \qquad\qquad + 28.72 \text{ miles per second.} \end{aligned}$$

For the instant of observation the Nautical Almanac gives

$$\odot = 242^\circ\ 41'.5;$$

and for this argument Table II gives

$$\log V_a = 1.2709, \qquad i = -\ 35'.5.$$

The solution of (5) is therefore

$$\begin{aligned} \log V_a &= \log 18.66 = 1.2709 \\ \sin(\lambda - \odot + i) &= \sin(184^\circ\ 59'.0) = 8.9388_n \\ \cos\beta &= \cos(-5^\circ\ 28'.5) = 9.9980 \\ \log v_a &= \qquad\qquad\qquad 0.2077 \\ v_a &= \qquad\qquad + 1.61 \text{ miles per second.} \end{aligned}$$

The value of the Moon's longitude given by the Nautical Almanac is

$$☾ = 173^\circ.$$

The solution of (6) is therefore

$$\begin{aligned} \log V_m &= \log 0.01 \qquad\quad = 8.00 \\ \sin(\lambda - ☾) &= \sin 255^\circ \qquad\quad = 9.98_n \\ \cos\beta &= \cos(-\ 5^\circ\ 28'.5) \ = 0.00 \\ \log v_m &= \qquad\qquad\qquad\quad 7.98 \\ v_m &= \qquad\qquad + 0.01 \text{ miles per second.} \end{aligned}$$

The hour angle of the star at the instant of observation was

$$t = 21^h\ 21^m;$$

and the value of v_d, equation (7), given by Table III is

$$v_d = +\ 0.14 \text{ miles per second.}$$

Applying the three corrections v_a, v_m, and v_d to the observed velocity of the star v_s, we obtain the star's velocity with reference to the solar system,

$$+\ 30.48 \text{ miles per second,}$$

the positive sign indicating a recession.

TABLE I.

Velocities corresponding to Displacements of one tenth-metre.

Line.	V_s	log V_s	Wave-Length.	V_s	log V_s
C	28.39	1.4532	5300	35.16	1.5460
D_1	31.60	1.4996	5200	35.83	1.5543
D_2	31.63	1.5001	5100	36.54	1.5627
D_3	31.71	1.5012	5000	37.27	1.5713
1474	35.05	1.5446	4900	38.03	1.5801
E_1	35.35	1.5484	4800	38.82	1.5890
b_1	35.94	1.5556	4700	39.64	1.5982
b_4	36.06	1.5570	4600	40.51	1.6075
5005	37.23	1.5709	4500	41.41	1.6171
F	38.33	1.5835	4400	42.35	1.6268
$H\gamma$	42.93	1.6327	4300	43.33	1.6368
G	43.25	1.6360	4200	44.36	1.6470
$H\delta$	45.42	1.6573	4100	45.45	1.6575
H	46.95	1.6716	4000	46.58	1.6682
K	47.37	1.6755	3900	47.78	1.6792

TABLE II.

The Earth's Orbital Velocity V_a and the Deviation i when the Sun's Longitude is $\odot$.

$\odot$	V_a	log V_a	i	$\odot$	V_a	log V_a	i
			′				′
0	18.48	1.2667	+ 56.5	180	18.36	1.2639	− 56.5
10	18.43	1.2655	+ 57.5	190	18.42	1.2652	− 57.5
20	18.37	1.2642	+ 57.0	200	18.47	1.2664	− 57.0
30	18.32	1.2630	+ 55.0	210	18.52	1.2677	− 54.0
40	18.27	1.2618	+ 50.5	220	18.57	1.2688	− 50.0
50	18.23	1.2607	+ 45.5	230	18.61	1.2698	− 44.5
60	18.19	1.2598	+ 38.5	240	18.65	1.2707	− 37.5
70	18.16	1.2590	+ 30.0	250	18.68	1.2715	− 29.5
80	18.13	1.2584	+ 21.0	260	18.71	1.2720	− 20.5
90	18.12	1.2581	+ 11.5	270	18.72	1.2724	− 11.0
100	18.11	1.2579	+ 1.0	280	18.73	1.2725	− 1.0
110	18.11	1.2580	− 9.0	290	18.72	1.2724	+ 8.5
120	18.13	1.2583	− 19.0	300	18.71	1.2721	+ 18.5
130	18.15	1.2589	− 28.0	310	18.69	1.2716	+ 27.5
140	18.18	1.2596	− 36.5	320	18.66	1.2709	+ 35.5
150	18.22	1.2605	− 44.0	330	18.62	1.2700	+ 43.0
160	18.26	1.2615	− 50.0	340	18.58	1.2690	+ 49.0
170	18.31	1.2627	− 54.0	350	18.53	1.2679	+ 53.5
180	18.36	1.2639	− 56.5	360	18.48	1.2667	+ 56.5

TABLE III.

$$v_d = -0.29 \sin t \cos \delta \; (37^\circ \; 20')$$

Hour Angles.		Declinations.										Hour Angles.	
t	t	0°	±10°	±20°	±30°	±40°	±50°	±60°	±70°	±80°	±90°	t	t
h m	h m											h m	h m
0 0	12 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12 0	24 0
0 30	11 30	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00	12 30	23 30
1 0	11 0	0.06	0.06	0.06	0.05	0.05	0.04	0.03	0.02	0.01	0.00	13 0	23 0
1 30	10 30	0.09	0.09	0.08	0.08	0.07	0.06	0.04	0.03	0.02	0.00	13 30	22 30
2 0	10 0	0.12	0.11	0.10	0.10	0.09	0.07	0.06	0.04	0.02	0.00	14 0	22 0
2 30	9 30	0.14	0.14	0.13	0.12	0.11	0.09	0.07	0.05	0.02	0.00	14 30	21 30
3 0	9 0	0.16	0.16	0.15	0.14	0.13	0.10	0.08	0.06	0.03	0.00	15 0	21 0
3 30	8 30	0.18	0.18	0.17	0.16	0.14	0.12	0.09	0.06	0.03	0.00	15 30	20 30
4 0	8 0	0.20	0.20	0.19	0.17	0.15	0.13	0.10	0.07	0.03	0.00	16 0	20 0
4 30	7 30	0.21	0.21	0.20	0.18	0.16	0.14	0.11	0.07	0.04	0.00	16 30	19 30
5 0	7 0	0.22	0.22	0.21	0.19	0.17	0.14	0.11	0.08	0.04	0.00	17 0	19 0
5 30	6 30	0.23	0.23	0.22	0.20	0.18	0.15	0.11	0.08	0.04	0.00	17 30	18 30
6 0	6 0	0.23	0.23	0.22	0.20	0.18	0.15	0.12	0.08	0.04	0.00	18 0	18 0

$_d$ i + for stars observed east of the meridian. v_d is — for stars observed west of the meridian.

ON THE SPECTRA OF BINARY STARS.*

W. H. S. MONCK.

The following table may perhaps elucidate the questions relative to binary stars raised by Mr. Gore, Mr. Maunder and myself. It is the result of a comparison of Mr. Gore's Catalogue of Binary Stars with the Draper Catalogue, and, I think, contains all stars common to both catalogues. It shows, I think (1) The superior relative brightness of Sirian to Solar stars; (2) The numerical superiority of Solar stars among these binaries.

Name of Star.	Relative Brightness	Spectrum.	Name of Star.	Relative Brightness	Spectrum.
66 Piscium	9.77	A	γ Virginis	4.92	F
14 (*i*) Orionis	4.09	A	42 Comæ	2.46	F
12 Lyncis	14.01	A	44 (*i*) Bootis	2.07	F ?
Sirius	6.35	A ?	η Coronae Borealis	1.40	F
φ Ursæ Majoris	21.26	A	μ Draconis	4.21	F
Castor	38.12	A	Σ 2173	0.88	F ?
25 Canum Venaticum	7.28	A	ξ (51) Scorpii	5.70	F ?
γ Coronæ Borealis	20.83	A	99 Herculis	1.13	F
λ Ophiuchi	28.16	A	τ Ophiuchi	7.35	F
δ Cygni	31.29	A	β Delphini	6.85	F
λ Cygni	11.01	A	δ Equulei	2.12	F
Σ 3121	0.21	E	τ Cygni	4.28	F
ω Leonis	4.06	E	ζ Aquarii	9.21	F
OΣ 234	1.80	E ?	ξ Ursæ Majoris	1.00	G
OΣ 215	2.08	E	ξ Bootis	0.34	G
σ Coronæ Borealis	1.77	E	ζ Herculis	4.67	G
Σ 3062	0.68	F	Σ 2107	1.74	H ?
η Cassiopeiæ	0.51	F	61 Cygni	0.07	H
Σ 1037.	1.83	F	π Cephei	11.07	H ?
ζ Cancri	2.90	F	γ Leonis	92.99	K
Σ 228	1.17	F	70 (*p*) Ophiuchi	0.30	K
OΣ 235	2.11	F	36 Andromedæ	6.23	M ?

Total: First type (Sirians) 11, second type (Solars) 32, third type 1.

A cursory examination leads me to think that in the case of double stars whose orbits cannot be computed in consequence of their very slow motion (whether owing to their great distances from us or their small masses) the proportion between Solar and Sirian stars is reversed.

THE SPECTRA OF STARS IN THE MILKY WAY.†

BY J. E. GORE F. R. A. S.

Professor Pickering finds that the majority of the stars in the Milky Way show spectra of the first or Sirian type. I have made

* Communicated by the author.

† The Journal of the British Astronomical Association, December, 1891.

a careful enumeration of the stars in the Draper Catalogue of Stellar Spectra which lie in the Milky Way and its branches, as drawn by Heis, and the following table shows the results I have found:—

Spectrum.	No. of Stars.	Total.	Type.	Remarks.
Sub-group A	1,893			
" B	44			
" C	3	1,940	I.	Sirian type
" D	—			
" E	237			
" F	315			
" G	14			
" H	454	1,100	II.	Solar type.
" I	45			
" K	34			
" L	1			
" M	15	15	III.	α Herculis type.
" Q	6	6		Spectra which differ from those of types I, II, III, and IV.
Grand Total	-	3,061		

The above result shows that of the stars in the Milky Way to about the 7th magnitude, 63.4 per cent are of the first type, and 36.6 per cent of the second and other types.

For the preceding half of the Milky Way visible in these latitudes (0^h to 9^h R. A.), I find that 1,078 stars are of type I. out of a total of 1,608, or a percentage of 67.

The richest region in stars of the first type lies between R. A. $3^h\ 16^m\ 8$ and $3^h\ 25^m\ 5$ (Epoch 1900) where out of 63 stars, no fewer than 52, or 82½ per cent are of type I.

It will be seen that there are no stars of Sub-group D in the Milky Way, and only one star of Sub-group L.

As Mr. Monck has pointed out, the fact of Stars of the Sirian type being probably brighter, surface for surface, than those of the second or solar type, would suggest that stars of the first type would be visible at greater distances than those of the second. I find that the great majority of stars with large proper motions,—generally supposed to indicate proximity to our system,—have spectra of the second type, and this is of course evidence in favor of Mr. Monck's view. The preponderance of first type stars in the Milky Way would therefore suggest that it lies further from us than the generality of the visible stars, a conclusion which has previously been arrived at from other considerations.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 352 for information in regard to illustrations, reprint copies, etc.

The New Star in Auriga.—Since the publication of our March number much additional information has been received in regard to Nova Aurigae. Though shown by the Harvard photographs to have been visible to the naked eye for weeks before the announcement of its discovery, the new star was not known to exist until Mr. T. D. Anderson, of Edinburgh, armed with a small pocket telescope and Klein's Star Atlas, satisfied himself on January 31 that a stranger had appeared in Auriga. Here is encouragement indeed for the amateur with small instrumental equipment. It seems that there are cases in which the naked eye (for the first glimpses of the Nova were obtained by Mr. Anderson without any aid to vision), or at best a telescope magnifying ten times, can outdo the largest and most searching instrument.

It is an interesting fact that as observed at Greenwich the Nova seemed to have a "slightly fuzzy" appearance, and its light was described as "not so piercing" as that of other stars in the same field. Dr. Common, observing at Ealing with his 5-foot reflector, did not note any "fuzziness." He found the spectrum to be crowded with bright lines, notable among which were C, F and G. "There was a bright line at or near D, one fairly bright between C and D (about 617), and several faint lines near both C and D. In the green between D and F three very strong bright lines were visible. One of these was found by comparison to be practically coincident with the 517 hydrocarbon fluting, while another was probably the 5005 nebula line. Several faint lines were observed in the green. Between G and F there were certainly three bright lines." (*Observatory*, March, 1892). The dispersion employed is not stated. Mr. Lockyer saw no nebulosity about the star either in a 3-foot reflector or 10-inch refractor, nor was any shown in a photograph taken by him with a 3½-inch Dallmeyer lens after three hours exposure. Father Denza, however, at the Observatory of the Vatican, noticed certain peculiarities in the photographed images of the star. Two sets of photographs were made by him on the evening of Feb. 7, five images being obtained on each plate, which was moved a short distance in declination between each successive exposure. Five minutes, and twenty, fifteen, ten and five seconds, were the times given. As the star was shown with the shortest exposure, in spite of bright moonlight, Father Denza concludes that it was of the 5th magnitude at that time. He remarks further: "In the two photographs the image of the star is not so sharp as the images of the other stars on the plate, which are perfectly round; it has a somewhat soft appearance, which gives reason to believe that this star has recently experienced some disturbance." Father Denza has also determined the position of the Nova from the photographs (a *reseau* was imprinted on one of the plates), by micrometer measures, and with the meridian circle. The latter measures give: $\alpha = 5^h\,25^m\,3^s.4$, $\delta = +\,30°\,21'\,42''.0$. (*Comptes rendus*, Feb. 22, 1892.)

At a meeting of the Royal Society on Feb. 11, Mr. Lockyer presented a paper on the photographic spectrum of the new star, in which he announced that "the bright lines K, H, h and G are accompanied by dark lines on their more refrangi-

ble sides." As may be seen by referring to the photograph of the spectrum in the last number of ASTRONOMY AND ASTRO-PHYSICS, this interesting fact had already been discovered by Professor Pickering. In his communication Mr. Lockyer gave the following list of the wave-lengths of twenty bright lines in the photographic spectrum, determined by direct comparison with lines in α Cygni: 3933, 3968, 4101, 4128, 4172, 4202, 4226, 4264, 4291, 4310, 4340, 4383, 4412, 4434, 4469, 4518, 4555, 4587, 4625, 4860. He considers it probable that many of these lines are coincident with lines in the Orion nebula, Orion stars, and Wolf-Rayet stars. Other lines more refrangible than K, and probably including members of the ultra-violet hydrogen series, were also obtained on the plates. Mr. Lockyer refers to his "meteoritic hypothesis" for an explanation of the new star, and remarks that if subsequent photographs continue to show the dark lines displaced to the more refrangible side of the bright ones, "the spectrum of Nova Aurigae would suggest that a moderately dense swarm is now moving towards the Earth with a great velocity and is disturbed by a sparser one which is receding. The great agitations set up in the dense swarm would produce the dark-line spectrum, while the sparser swarm would give the bright lines." (*Nature*, Feb. 18, 1892.)

From the *Observatory* we learn that Professor Vogel has photographed the spectrum of the Nova with the Potsdam spectrograph, and finds that the hydrogen line used for comparison falls between the dark and bright lines in the star. The displacements for the two components are unequal, the bright lines indicating the greater velocity.

Dr. and Mrs. Huggins have continued their observations, and we add from the *Observatory* a communication presented by them to the Royal Society on Feb. 24.

"Perhaps the most noticeable feature to the eye in the star's spectrum was the great brilliancy of the hydrogen lines at C, F, and G; but the point of greatest interest was obviously that two of these lines, F and G—and we have since observed the same with C—were accompanied each by a strong absorption line on the side towards the blue. Comparison with the lines of terrestrial hydrogen, while confirming the obvious presumption that the star lines were really those of hydrogen, showed at once a large motion of recession of the bright lines and a motion of approach of a similar order of magnitude of the hydrogen which produced the absorption.

"A photograph which we have since taken gives the star's spectrum as far in the ultra-violet as about λ 3200. On this plate we see not only the other hydrogen lines at h and H, but also the series beyond, which is characteristic of the white stars—bright, with dark absorption lines on the blue side.

"Besides the hydrogen series there appear to be other lines doubled in a similar manner, including the sodium lines at D. The line K is strongly impressed upon the plate, but in our photograph it is not followed by an absorption so strong as in the case of H.

"In the green part of the spectrum three very brilliant green lines are seen on the red side of F. One of these falls not far from the position of the chief nebular line; but even when the shift of the spectrum is taken into account, we can scarcely regard this line as the true nebular line. In this connection it was a point of some importance to find that the strong and very characteristic line of the Orion nebula, which falls about λ 3725, is absent in our photograph of the Nova.

"The third line from F is rather broad and resolvable into lines. It falls partly upon the more refrangible pair of the magnesium triplet at b, but its character and position do not permit us to ascribe it to either magnesium or carbon.

"We wish to mention an early photograph of this star taken on the 3d instant by Father Sidgreaves, at Stonyhurst, which we had the privilege of examining. This successful photograph extends from h to near D, and shows the remarkable doubling of many of the bright lines by dark ones—a feature which was at once noticed by Father Sidgreaves and ourselves.

"In our photograph the spectrum of the star, which extends on the plate as far into the ultra-violet as our photographs of Sirius, is crowded throughout its entire length with dark and bright lines. In the visible region the number of bright lines and groups, including the double line of sodium and lines in the neighborhood of C, is also very great.

"We prefer in this preliminary note not to enter into any more detailed discussion of the star's spectrum, nor to refer to the probable phenomena which may now be in progress in this celestial body. We reserve these considerations for the present."

It will be remembered that in Professor Pickering's article in our last number mention was made of the fact that the dark hydrogen lines in the spectrum of Nova Aurigae are shown double in the photographs. This could even be seen in the half-tone cut which accompanied the paper. The interpretation of the duplicity as being the result of the relative motion of certain bodies in the complex system of the Nova was the most natural one to make in the light of data derived from other cases of a similar nature, and this conclusion is now greatly strengthened by the following important announcement, which we have just received from Professor Pickering.

A Change in the Spectrum of Nova Aurigæ.—From an examination of sixteen photographs of the spectrum of Nova Aurigae taken with the 11-inch Draper telescope between February 4 and February 16, 1892, Mrs. Fleming finds that a distinct change has taken place both in the width and distance apart of the components of the dark hydrogen lines. EDWARD C. PICKERING.

Harvard College Observatory,
Cambridge, Mass., March 11, 1892.

A letter received just as we go to press from Rev. A. L. Cortie informs us that Father Sidgreaves has obtained many photographs of the spectrum of the Nova in addition to the one mentioned by Dr. Huggins. They show over 100 bright and dark lines and bands, and also the doubling of the bright and dark lines. As orthochromatic plates were used the spectra extend from D to h. The most conspicuous lines are D_3, F, G and h, and strong bands are shown near λ 500 and near b. Photographs were secured on Feb. 4, 8, 11, 12, 13, 15, 16, and 18, and in this time the spectrum was found to have undergone certain changes. We have not yet learned the precise nature of these changes.

Magnetic Perturbations and the Great Sun-Spot.—That the great spot group which appeared at the Sun's eastern limb on Feb. 4, and was not far from the center of the disc on Feb. 13, should be in some way connected with the wide-spread magnetic storm and brilliant auroras of the latter date seems far from improbable, but we have nothing to warrant us in assuming a direct relation of cause and effect. As Dr. Veeder well puts it in a letter to the *New York Herald*, "If big Sun spots produce auroras, why did not this one continue to do so throughout the entire time that it remained visible?" It might be held that some great disturbance in the spot group occurred simultaneously with the magnetic

storm, but nothing to parallel the classic observation of Carrington and Hodgson was recorded. It is true that observations made at Kenwood Observatory showed more activity, and greater distortion of the C line in the spot group on the date in question than at any other time of observation, but nothing of a very remarkable nature was seen. M. E. Marchand, however, thinks that Sun-spots produce an effect on terrestrial magnetism when they pass the center of the Sun's disc: "The very marked magnetic perturbation of Feb. 13-14, 1892, verifies in a very remarkable manner the general law which I deduced in 1887 from observations made at Lyons (France), on magnetism and the solar spots and faculae. (*Comptes rendus*, Jan. 8, 1887.) In fact solar observations on Feb. 10 and 11 show a very large spot group, *visible to the naked eye*, in latitude — 26°, followed by another group of small spots in latitude — 18°. The passages of these two groups over the central meridian took place on the following dates: Feb. 11.9 for the first; 13.1 for the second. Very extensive faculae connected these two groups, moreover, and extended far behind the second. Now the magnetic perturbation commenced on Feb. 13.2; that is to say, immediately after the passage of the second group of spots.

"Let us add that the *region of activity* in which these two groups occur, has long existed on the solar surface, but it has not always contained spots. In June, 1891, for example, it contained only faculæ; at other returns it was the seat of faculæ and pores. It has produced a magnetic perturbation at each of its passages over the central meridian; some of these perturbations have been comparatively strong, for example those of Jan. 17, 1892, Nov. 20, 1891, Oct. 24, 1891, Sept. 28, 1891, Aug. 29, 1891, Aug. 3, 1891." (*Comptes rendus*, Feb. 22, 1892.)

The "general law" referred to by M. Marchand is given in the *Comptes rendus*, Jan. 10, 1887, and may be translated as follows: "Each of the maxima (in a curve of magnetic declination) sensibly coincides with the passage of a group of spots or a group of faculæ at its shortest distance from the center of the solar disc." Diagrams are given which show the variation in the curve of intensity from December, 1885, to October, 1886, and the positions of spots or faculæ with reference to the central meridian of the Sun are noted above the maxima of the curve. In most cases the agreement is very good, but we cannot therefore assent that the *general* nature of the law has been proved, though we fully recognize that something more than chance coincidence is suggested. During the latter half of the period covered by the diagrams the Sun was frequently observed to be entirely free from spots, and the faculæ were therefore supposed to be responsible for most of the magnetic perturbations. "In this latter case, the faculæ have been generally observed up to quite a distance from the two limbs; it could be concluded that they must have persisted until they reached the center, although observation was rarely extended so far." But even taking it for granted that this assumption was a fair one, was it true that the passage of *every* facula across the central meridian was attended by a magnetic perturbation? Since we have been able at Kenwood Observatory to record faculae on all parts of the disc with equal ease by the aid of the spectroheliograph there has rarely been a time when at least one facula has not been crossing the central meridian. For the faculae are of great extent, and very irregular form, and they may require days to pass a fixed point. We therefore regard M. Marchand's theory with some hesitation.

Another theory which has been strongly advocated by Dr. M. A. Veeder and others, holds that solar disturbances do not as a rule produce any noticeable effect on terrestrial magnetism except when coming into view by rotation on the Sun's eastern limb. In the letter to the *New York Herald* from which we have

already quoted Dr. Veeder remarks: "It cannot be reiterated too often that the magnetic effect of solar disturbances is felt almost exclusively when they are exactly at the eastern limb. I have a record of numerous instances in which the most tremendous outbreaks located elsewhere have been attended by scarcely any auroral or magnetic effect whatever. On June 17, 1891, for example, there was a disturbed area at the western limb of the Sun, in connection with which enormous velocities of eruption were recorded. Nevertheless the day was magnetically very quiet." (We may mention here that Mr. Whipple has examined the magnetic records of the Kew Observatory for June 17, and fails to find even the slight disturbance shown by Mr. Turner in the diagrams given in the January number of ASTRONOMY AND ASTRO-PHYSICS.) "Compare this with what happened August 28, 1891, when a spot which was also in the same region which has recently been the seat of the great spot group above mentioned came into view. Instead of almost perfect quiet the magnets were violently disturbed and there was a brilliant aurora." In a letter from Dr. Veeder we learn that there was a brilliant aurora on the night of Feb. 29, the date of the expected return of the disturbed section of the Sun which contained the great spot group. In another letter dated March 13, Dr. Veeder writes: "Strong auroral streamers and patches were seen last evening from 8.07 to 8.30 through breaks in the clouds, and this morning there is upon the Sun's eastern limb a spot group appearing by rotation. This is the recurrence of the Feb. 13-14 aurora and solar disturbance exactly on time. This periodicity and association of phenomena demonstrates conclusively that the 'big Sun-spot' west of the meridian was not responsible for either of these auroral displays." Dr. Veeder is in perfect accord with M. Marchand on one point at least; they agree in the belief that the size of spots has nothing to do with their magnetic effect.

We are ourselves inclined to favor the "eastern limb" theory, but the time has not yet come to definitely accept any. The accumulation of data is now more desirable than the formulation of theories, though these will play a very useful part in guiding investigation.

Several notes on the magnetic storm and the great spots have been gathered from various sources, and are given below.

A Magnetic Disturbance.—The following letter from the superintendent of the Kew Observatory appears in *Nature* for Feb. 18, 1891:

Our attention having been directed for some days past towards a spot of unusual size upon the Sun's disc we were not by any means surprised to observe, as doubtless many of your readers elsewhere also did, an aurora of great beauty on Saturday night last; nor was our anticipation of seeing a magnetic disturbance portrayed upon the magnetograph records disappointed in the morning, for when the sheets were changed and the photographs developed, we saw that perturbations more violent than any which had been recorded at Kew for the past ten years had been in progress since about 5.45 A. M. of Feb. 13.

The magnets were very quiet on Friday, but early on Saturday morning they became disturbed. The easterly declination slightly increased until about 5.40 P. M., whilst both horizontal and vertical forces similarly increased in intensity, more especially between 4 and 6 P. M. They further diminished in force after 10 P. M., and their changes became very rapid from 12 midnight to 2 A. M., whilst at the same time the declination proceeded to its extreme westerly position. Subsequently, the fluctuations in magnetism became much reduced in extent, and the whole disturbance gradually diminished and died out about 4 P. M. of Sunday.

The Kew magnetometers were not able to record the complete extent of the vibrations to which the needles were subjected, nor could the entire change of force be secured in the field of the instrument. The limits, however, clearly recorded were 2° of declination from .1760 to .1830 of horizontal force, and from .4350 to .4420 units of vertical force expressed in C. G. S. measure in absolute force.

G. M. WHIPPLE,
Kew Observatory, Richmond, Surrey, Feb. 16. Superintendent.

Great Magnetic Disturbance of 1892, February 13-14.—The magnetic disturbance commenced in all elements on February 13 at 5^h 30^m, Greenwich Civil Time, by a sudden increase of declination, horizontal force, and vertical force, accompanied by a strong manifestation of earth currents. Large motions continued to be registered throughout the day and following night; between February 13 14^h and February 14 5^h they were unusually large, amounting in declination to 1° and more, the trace having passed off the sheet for one hour shortly after midnight. In the horizontal force the disturbance exceeded 0.03 parts of the whole horizontal force, the trace having similarly passed off the sheet for nearly half an hour at about 22^h and for more than 1½ hours from shortly before 1^h to $2½^h$. In vertical force the disturbance was also great, the trace going off the sheet on both sides, in the direction of increasing force from $14½^h$ to 19^h, and the direction of decreasing force from $0½^h$ to 2^h; the range probably exceeded 0.02 parts of the whole vertical force. The disturbance ceased on the afternoon of February 14. An aurora was seen at Greenwich between 0^h and 1^h on February 14.

A preliminary sudden movement is a common feature of magnetic storms; sometimes the disturbance follows on at once, sometimes it is a premonitory sign of disturbance to follow in a lesser or greater number of hours. The latter was the case in the celebrated 1859 Sun-spot and the magnetic disturbance. Mr. Ellis has recently been making an examination of some peculiarities connected with the initial movements observed in magnetic storms, and expects to arrive at interesting information in regard to the question as to how closely these movements are simultaneous at different places, and also on other points.

The Magnetic Storm of Feb. 13-14.—M. Mascart has the following note in the *Comptes rendus* for Feb. 22:

The recording instruments of the Observatories of Nice, Toulouse, Clermont and Besancon uniformly imprinted this disturbance, with all the circumstances determined by the stations of Perpignan, Lyon, Nantes and Parc Saint-Maur; the details of the phenomena will form the object of a later investigation.

Moreover, the accompanying aurora borealis, first noted in the United States, was observed in Europe as well.

On Feb. 14, from 1^h to 1^h 10^m A. M. (Paris M. T.), M. A. Forel saw at Morges a very beautiful aurora borealis; the telegraph operator of the Morges–Rolle line was awakened about 12^h 25^m A. M, by the bell ringing of its own accord.

The same day, between midnight and 1^h A. M., M. P. Lefebre observed at Troyes "an aurora borealis of considerable intensity, since the phenomenon was easily visible in spite of the brilliancy of the full Moon. A faint purple light first appeared in the north; as it continued to rise higher, the center was sensibly displaced from east to west. At the moment of its greatest brightness, whiter and more brilliant vertical streamers were seen at intervals. Finally the phenomenon disappeared behind clouds, after having undergone a new displacement in a direction opposite to that of the first."

M. de Roquigny-Adanson informs me that the aurora was observed at Parc-de-Baleine by a gamekeeper. * * * * * The aurora was also seen in the Mediterranean, in the neighborhood of the coasts of Provence, at Rome, Brussels, London, in Canada, in the United States above the 36th parallel, etc.

Note on a Sun-spot Observed at Meudon Observatory from Feb. 5 to Feb. 17, by M. J. Janssen.—(*Comptes rendus*, Feb. 22, 1892.) M. J. Janssen exhibited to the Academy the photographs of the Sun obtained on Feb. 5, 9, 12 and 17, on which is shown one of the largest spots observed during recent solar periods.

The fact which renders this spot particularly remarkable and allowed it to be easily seen with the naked eye, is the great extent of the surface disturbed (the diameter of which is about one-seventh the diameter of the solar disc), and the great number of nuclei distributed over this surface. Two of these nuclei united in the same penumbra were from six-tenths to eight-tenths of a minute of arc in diameter, which closely approximates the dimensions of the largest nuclei ever observed.

The large scale on which these photographs have been obtained permits of the study of the movements and changes which the nuclei underwent from the appearance of the spot on Feb. 5 to Feb. 19, at which date it was close to the limb. This study is complicated by the fact that there enter into it as elements the variation in time of rotation with the heliocentric latitude—a variation very perceptible in the present case, on account of the extent of the spot in the direction of the solar meridian—together with certain proper motions, and finally the variation of the forces which produced this great photospheric disturbance If the results of this study are of sufficient interest the Academy will be informed of them.

In regard to the question of a connection between the phenomena of Sun-spots and terrestrial magnetic disturbances, M. Janssen sees nothing in the facts so far established which would as yet authorize us in admitting this correlation. However, as nothing should be rejected *a priori*, and as the study of this question cannot be otherwise than profitable in the advancement of science, it is desirable that the number of meteorological and magnetic observatories be increased, principally in the Southern Hemisphere, in order that it may become possible to separate out from a mass of electric and magnetic effects those which may have a general and simultaneous character over an entire terrestrial hemisphere, for it is evident that only phenomena of this order can be attributed to solar action.

Photography of the Great Sun-Spot at the Lick Observatory.—We are indebted to the Lick Observatory for an excellent copy on glass of a photograph of the Sun taken when the great spot was nearest the center of the disc. The photograph was accompanied by the following letter from Professor Campbell:

LICK OBSERVATORY, Mount Hamilton, March 8, 1892.

Dear Professor Hale:

I take pleasure in complying with your request for a copy of one of our photographs of the great February Sun-spot. It is a positive contact copy of a negative taken by Professor Schaeberle and myself with the 40-foot photoheliograph on Thursday, Feb. 11, 1892. 10h 35m 48s Pac. St. Time. We have secured photographs of the spot every clear day that it has been on the visible hemisphere of the Sun since Feb. 9, on which date it was detected here by Professor Schaeberle by the naked eye. Unfortunately, however, the seeing has usually been poor, and the definition is not as good as we should wish.

Yours very truly,

W. W. CAMPBELL.

Area and Position of the Great Sun-Spot as Determined at Greenwich.—In the Journal of the British Astronomical Association, Dec. 1891, Mr. E. Walter Maunder gives the following note on the great Sun-spot:

Although it is only two years and a half since the time of absolute minimum, the reviving energy of the Sun has already displayed itself in a group of spots which completely dwarfs any witnessed during the preceding cycle. A group appeared at the east limb on February 5, crossing the meridian on February 11, and disappearing at the west limb on February 13, which had an area on February 13 of more than 2850 millionths of the Sun's visible surface, the greatest area attained by the group of November 12-25, 1882, the largest group of the 1878–89 cycle, being 2425 millionths. As in the case of the 1882 spot, the giant group has been accompanied by violent and characteristic magnetic disturbances, and by brilliant aurorae. The center of the group on February lay in hel. long. 260°, and hel. lat. 23° S.

An Equatorial Group of Sun-Spots.—As is well known, Sun-spots vary not only in number, but in latitude as well during a Sun-spot cycle. Just after a minimum, at the beginning of a new cycle, the spots which have been frequenting lower and lower latitudes since the previous maximum soon disappear, and are replaced by new spots in higher latitudes. It is extremely rare that a spot is seen near the equator in the early part of a new cycle, and we are therefore interested in a note by Mr. J. S. Townsend in the Journal of the British Astronomical Association (Dec., 1891), in which he gives his observations of a small group of spots seen near the equator from Nov. 20 to Nov. 25, 1891. The heliocentric latitude of the group varied between + 1° and + 6°, and the longitude between 261° and 267°. As the last minimum occurred in 1889, the low latitude of the group in question is quite remarkable.

Observations of Eruptive Prominences by Mr. E. E. Read, Jr., at Camden, N. J.—On Feb. 18, from 10 to 12 A. M., Mr. Read observed a very bright prominence extending from P. A. 222° to 230°. The highest part was about 30″ above the photosphere, and the form changed so rapidly that it was not similar in any two consecutive quarters of an hour. The distortion of the C line was mostly toward the red. Reversals were observed as follows, the positions of lines being taken from Rowland's map: C, D_1, D_2, D_3, 5371.7, 5363., 5328.1, *1474 K*, 5276.2, 5269.5, 5234.8, 5227.4, 5226.6, 5208.6, 5206.2, 5204.7, 5188, b_1, b_2, b_3 b_4, 5018.6, 4957.7, 4924.1, F.

Bad air and haze made it necessary to stop observation at F. The b lines were (except C, D_3 and F) the highest and brightest, extending about half way up. The other lines were low down.

On Feb. 19 the prominence was again seen for a few moments, and found to be about 60″ high. C was considerably distorted in both directions.

On Saturday, March 6, Mr. Read observed a prominence at P. A. 232°, which was described in the note-book as follows: "bright, probably metallic, but definition too poor to see any reversals save hydrogen and D_3." The same day at 7:30 P. M. he saw a distinct, but not bright, aurora, which lasted for 30 minutes. On March 7, at 10:30 A. M., a prominence was seen at P. A. 234° which reached an elevation of 162″ and showed great activity. "The base was a perfect cyclone, the motion being in both directions. At 11 o'clock this prominence had risen to about 4′, the base having almost entirely vanished. By noon there was nothing visible at that point." Two drawings which accompany the letter show the form of the prominence at 10:15 and 11 A. M. At the latter hour the prominence seems to have been blown into fragments.

Comparative Photographic Spectra of the Sun and Metals, by Mr. F. McClean.— Though it is now many years since photography was first successfully employed in the registration of metallic spectra, the beautiful photographs recently published by Mr. McClean form the first comprehensive series to be put into the hands of spectroscopists for general use. The set of twelve large plates before us, which we owe to the kind liberality of Mr. McClean, contains the spectra of the Sun and fifteen metals from λ 3800 (above H) to λ 5750 (near D) or more than half the visible spectrum, on the scale of Angstrom's chart. They are divided into two Series; of these, Series I contains the spectra of the Sun, iron, platinum, iridium, osmium, palladium, rhodium, ruthenium, gold and silver. The last eight constitute the platinum group of metals. Series II contains the spectra of the Sun, iron, manganese, cobalt, nickel, chromium, aluminum and copper; these seven metals constituting the iron-copper group. As in all cases the metallic spectra were obtained from the spark discharge in air, the air spectrum is shown in all the photographs. These are mounted in parallel sections, and the air lines consequently run uniformly across the entire series. Though somewhat overexposed, owing to the fact that the metallic spectra require a longer exposure to bring out their lines properly, the air spectrum is quite sufficiently well shown to be included in the enumeration of the spectra contained in these maps.

Though every care was used to obtain metals in a pure state for the work, Mr. McClean remarks in the Note which accompanied the presentation of his photographs to the Royal Astrononomical Society that many further impurities will have to be eliminated. Calcium, for example, is almost universally present, its principal lines appearing in nearly every spectrum, and coinciding with marked groups in the solar spectrum. It appears most strongly in osmium and cobalt. Iron and barium are also common to many spectra.

Everyone familiar with spectrum photography, knowing by experience the amount of patient labor required in photographing the various regions where specially prepared plates and absorbing solutions are essential to success, will unite in congratulating Mr. McClean on the advanced stage of his extensive investigations. With the completeness of his laboratory and apparatus, and the excellent methods in use there in photographing and enlarging spectra, we are ourselves familiar from personal observation. In company with Mr. Ranyard, the well-known Editor of *Knowledge*, the writer enjoyed last summer a most interesting visit to Mr. McClean's home in Tunbridge Wells, England. The entire upper story of the house is fitted up as a laboratory, and a heliostat on the roof commands the horizon in almost every direction, thus making possible the photographic work on the high and low Sun spectrum which was carried on by its means. The light is reflected into a telescope fixed in the meridian at the angle of the pole, and a total reflecting prism at the eye-end allows the image of the Sun to be formed on the slit of the spectrograph. This instrument is provided with a Rowland grating with 14,438 lines to the inch, and the observing telescope has a focal length of about 36 inches. The photographs taken at the focus of the spectrograph are subsequently enlarged about 8½ times. The electric apparatus is very complete. In the cellar of the house a gas engine is employed to charge a large storage battery. The current from this is led to a motor in the laboratory, and this, in turn, drives an alternating dynamo. The alternating current supplies the primary of a specially constructed induction coil, and at the time of our visit a battery of about forty Leyden jars was connected in parallel with the secondary terminals. The extremely brilliant spark, perfectly adapted for spectroscopic work, was attended by a deafening rattle. We had the pleasure of examining some of the photographs of spectra under a microscope, but no testimony is

necessary as to the sharpness of the original negatives when such excellent definition is retained in the maps after a nearly nine-fold enlargement.

The photographs have been very creditably reproduced by the Direct Photo-Engraving Co., the Collotype process being employed.

Appointment of Sir Robert Ball as Professor Adams' Successor at Cambridge.—Though we are perhaps straying without our proper domain of astro-physics, we must allow ourselves the pleasure of congratulating Sir Robert Ball on the well-deserved honor conferred upon him. The Lowndean Professorship is for Astronomy and Geometry, but we unite with the Editors of the *Observatory* in the hope that the Cambridge Observatory will be put into the same efficient hands, that it may once more attain the important position which its relation with the University calls upon it to occupy.

Recent Publications.—We have received a number of important publications, some of which we should be glad to refer to more at length, but lack of space makes it impossible to mention more than the titles at present. They are as follows:

Washington Observations, 1887; Appendix 1, A Report upon some of the Magnetic Observatories of Europe; Appendix 2, Magnetic Observations at the U. S. Naval Observatory (1890); Appendix 3, Meteorological Observations and Results at the U. S. Naval Observatory (1883-1887).

Publications of the Lick Observatory, vol. I. (1887).

Lunar Radiant Heat, Measured at Birr Castle Observatory, During the Total Eclipse of Jan. 28, 1888. By Otto Bœddicker.

Transactions of the Astronomical and Physical Society of Toronto. (1891).

Publicationen des Astrophysikalischen Observatoriums zu Potsdam. (No. 28): Beobachtungen des Planeten Mars, von O. Lohse.

The Total Eclipse of the Sun, Jan. 1. 1889. A Report of the Observations made by the Washington University Eclipse Party.

A Mechanical Theory of the Solar Corona. By J. M. Schaeberle.

Exercises in Connection with the Presentation of the Ladd Observatory to Brown University.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR MAY.

Mercury will be "morning star" during May. He will be at greatest elongation, 25° 39′ west from the Sun, on the morning of May 17; but as he rises then only 40^m earlier than the Sun there will be little opportunity for observation.

Venus will continue to increase in brilliancy during May and, also increasing in declination, will be better situated for observation than in the preceding month. The phase changes from gibbous to crescent, the illuminated portion of the disk being 0.498 on May 1 and 0.298 on May 30. During these two months of April and May, if ever, we ought to be able to see the markings of Venus' surface and decide the question of her rotation.

Venus will be in conjunction with the Moon, 1° 53′ south, May 29, 1 A. M.

Mars is a morning planet, visible in the south, almost on a parallel with, and a considerable distance east of, the red star Antares. The two are of almost the

same brilliancy and color. The low altitude of Mars renders observations of his surface details difficult, yet under these unfavorable circumstances the principal markings can easily be seen. The phase of Mars is gibbous, 0.875 of the disk being illuminated on May 1. Mars will be in conjunction with the Moon, 3° 05′ north, May 17 at noon.

Jupiter is also a morning planet and may be seen in the east an hour before sunrise.

There is an interesting paper on "recent discoveries on Jupiter" by C. Flammarion, in the March number of *L'Astronomie.* It is illustrated by copies of drawings made during the past opposition by Messrs. Terby and Comas in France.

Saturn will be in excellent position for observation in the early evening during May. He is in the western part of the constellation Virgo, about half way between *Spica* and the familiar group of stars, The Sickle, in Leo (see chart p. 81). He is moving very slowly westward, will be stationary May 25, after which he will move eastward. Saturn will be in conjunction with the Moon, 2° south, on May 6 at 6 P. M. The rings are very nearly edgewise to us; the minimum apparent width will be reached during the latter part of May, when it will be only 0.25″.

Uranus is a little farther east than Saturn (see chart p. 81) in the eastern part of Virgo near the star λ. The month of May will be perhaps the best in the year for observations of this planet. There will be an occultation of Uranus by the Moon on the morning of May 10 which will be visible only in the western half of the United States.

We would call attention again to the occultation of Uranus on the night of April 12 between 10 P. M. and 1 A. M. central time, and hope that many observations of this rare phenomenon may be obtained.

Neptune will be in conjunction with the Sun May 29 and so cannot be seen during this month.

We have made many attempts during the past opposition to discern markings on the surface of this planet, using the 16-inch refractor of Goodsell Observatory, but have been unsuccessful. On each occasion of excellent seeing, the planet appeared at first look to be very slightly elongated, the direction of elongation being about 50° of position angle; but we never could be certain, after protracted examination, varying eye-pieces and position of eyes, of this elongation. It seemed also as if the planet were encircled by a whitish equatorial belt in the same position angle, which belt may have contributed to the impression of elongation.

MERCURY.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	1 33.7	+ 7 10	4 06 A. M.	10 37.6 A. M.	5 09 P. M.
15......	1 56.0	+ 8 18	3 44 "	10 20.6 "	4 57 "
25......	2 38.7	+12 21	3 31 "	10 23.9 "	5 17 "

VENUS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	6 05.2	+26 54	7 05 A. M.	3 08.3 P. M.	11 12 P. M.
15......	6 44.2	+26 29	7 06 "	3 08.0 "	11 10 "
25......	7 17.0	+25 20	7 07 "	3 01.5 "	11 56 "

MARS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	20 07.2	−21 54	12 41 A. M.	5 12.0 A. M.	9 43 A. M.
15......	20 27.3	−21 17	12 19 "	4 52.7 "	9 27 "
25......	20 47.0	−20 40	11 52 P. M.	4 29.2 "	9 06 "

JUPITER.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	0 44.4	+ 3 33	3 32 A. M.	9 49.0 A. M.	4 06 P. M.
15......	0 52.4	+ 4 23	2 57 "	9 17.5 "	3 38 "
25......	1 00.0	+ 5 09	2 22 "	8 45.8 "	3 10 "

SATURN.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	11 40.5	+ 4 46	2 21 P. M.	8 42.8 P. M.	3 05 A. M.
15......	11 39.6	+ 4 50	1 40 "	8 02.5 "	2 25 "
25......	11 39.2	+ 4 50	1 00 "	7 22.8 "	1 45 "

URANUS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	14 05.9	−12 13	5 53 P. M.	11 07.8 P. M.	4 22 A. M.
15......	14 04.4	−12 05	5 12 "	10 26.9 "	3 42 "
25......	14 03.0	−11 58	4 31 "	9 46.2 "	3 02 "

NEPTUNE.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	4 25.4	+20 8	6 01 A. M.	1 29.0 P. M.	8 57 P. M.
15......	4 27.0	+20 12	5 23 "	12 51.2 "	8 20 "
25......	4 28.5	+20 15	4 45 "	12 13.5 "	7 42 "

THE SUN.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	2 52.8	+16 32	4 44 A. M.	11 56.5 A. M.	7 09 P. M.
15......	3 31.9	+19 06	4 32 "	11 56.2 "	7 20 "
25......	3 51.8	+20 11	4 27 "	11 56.8 "	7 26 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.].

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

April 1892.		
16	12.1 a m	En es
	2.3	Di es
	3.0 p m	Te bs
	4.6	En an
	4.6	Mi en
	5.0	Te as
	10.0	Mi es
	10.9	En en
17	1.3	Di bn
	2.0	Te Ecl. R.
	3.2	Mi en
	3.2	Rh an
	3.3	En as
	3.7	Te en
	5.0	Di Ecl. R.
	5.7	Rh bn
	6.8	Di en
	8.6	Mi es
	10.3	RhEcl. R
18	12.2 a m	Rh en
	2.3 p m	Te as
	5.9	En es
	7.2	Mi es
	8.0	Di es
	10.2	Di ds
19	12.2 a m	En as
	1.1	Mi as
	1.4	Di bs
	4.7 p m	En en
	5.8	Mi es
	9.4	Rh es
	11.7	Mi as
April 1892.		
	11.9	Rh ds
20	2.8 a m	En es
	3.8	Rh bs
20	3.3 p m	Titan bn
	4.4	Mi es
	7.2	En an
	9.2	Titan dn
	9.6	Titan middle of Ecl. of uncertain duration.
	10.3 p m	Mi as
21	1.0 a m	Titan
	1.5	En en
	1.6 p m	Di es
	3.0	Mi es
	3.8	Di ds
	6.0	En as
	7.1	Di bs
	8.9	Mi as
	9.3	Di as
22	2.0 a m	Te es
	7.5 p m	Mi as
	8.5	En es
	10.5	Di an
23	12.7 a m	Di bn
	12.7	Te an
	6.2 p m	Mi as
	7.3	En en
	11.3	Te es
	11.6	Mi an
24	1.3 a m	Te ds
April, 1892.		
	3.0 p m	Di as
	4.1	Rh bs
	4.8	Mi as
	6.7	Rh as
	9.8	En an
	10.0	Te an
	10.2	Mi an
	12.0 midn	Te bn
25	4.1 p m	Di an
	6.3	Di bn
	8.6	En as
	8.6	Te es
	8.8	Mi an
	10.2	Di Ecl. R.
	10.6	Te ds
	11.8	Di en
26	1.5 a m	Te bs
	3.9 p m	Rh am
	6.5	Rh bn
	7.3	Te an
	7.4	Mi an
	9.3	Te bn
	11.2	Eu es
	11.2	Rh. Ecl . R.
27	12.6 a m	Te Ecl. R.
	12.9	Rh en
	1.0	Di es
	5.9 p m	Te es
	6.0	Mi an
	7.9	Te dn
	9.9	En en
	10.8	Te bs
April, 1892.		
28	2.1	Titan bs'
	2.2	Axis of Titan's shadow cone just outside the ball.
	2.4	En as
	3.9	Di Ecl. R.
	4.6	Te an
	4.6	Mi an
	5.1	Titan as
28	5.5	Di en
	6.6	Te bn
	9.9	Te Ecl R
	10.1	Rh es
	10.6	Mi en
	11.5	Te en
29	3.2	Te es
	3.3	Mi an
	4.9	En es
	5.2	Te ds
	6.6	Di es
	8.1	Te bs
	8.8	Di ds
	9.2	Mi en
	10.1	Te as
	11.3	En as
30	12.1 a m	Di bs
	3.7 p m	En en
	3.9	Te bn
	7.2	Te. Ecl. R.
	7.8	Mi en
	8.8	Te en

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl .... $+81°\ 17'$
Period .... $2d\ 11^h\ 50^m$

May	1	6 P. M.
	4	6 A. M.
	6	6 P. M.
	9	5 A. M.
	14	5 "
	19	5 "
	24	4 "
	29	4 "

S ANTLIÆ.

R. A. .... $9^h\ 27^m\ 30^s$
Decl .... $-28°\ 09'$
Period .... $0d\ 07^h\ 47^m$

May	5	8 P. M.
	6	8 "
	7	7 "
	8	7 "
	16	9 "
	17	8 "
	18	8 "
	19	7 "
	28	9 "
	29	8 "
	30	7 "
	31	8 "

δ LIBRÆ.

R. A. .... $14^h\ 55^m\ 06^s$
Decl .... $-\ 8°\ 05'$
Period .... $2d\ 07^h\ 51^m$

May	6	10 P. M.
	13	10 "
	20	9 "
	27	9 "

U CORONÆ.

R. A. .... $15^h\ 13^m\ 43^s$
Decl .... $+32°\ 03'$
Period .... $3d\ 10^h\ 51^m$

May	6	7 P. M.
	10	6 A. M.
	17	4 "
	24	2 "

U OPHIUCHI.

R. A. .... $17^h\ 10^m\ 56^s$
Decl .... $+\ 1°\ 20'$
Period .... $0d\ 20^h\ 08^m$

May	5	4 A. M.
	5	midn.
	6	8 P. M.
	10	5 A. M.
	11	1 "

U OPHIUCHI CONT.

May	11	9 P. M.
	15	5 A. M.
	16	1 "
	16	9 P. M.
	21	2 A. M.
	21	10 P. M.
	26	3 A. M.
	26	11 P. M.
	31	4 A. M.
	31	midn.

Y CYGNI.

R. A. .... $20^h\ 47^m\ 40^s$
Decl .... $+\ 34°\ 15'$
Period .... $1d\ 11^h\ 56^m$

May	3	5 A. M.
	6	5 "
	9	5 "
	12	5 "
	15	5 "
	18	4 "
	21	4 "
	24	4 "
	27	4 "
	30	4 "

Occultations of Stars by the Planets.

Date		Central Time of Conjunction.	Diff. of Decl.	Maximum Duration.	Magnitude of Star.
		h m	″	m	
		STARS NEAR VENUS.			
May	2	3 58 A. M.	+ 37	10.4	8.0
	3	4 20 P. M.	− 35	10.8	8.9
	4	6 46 A. M.	− 77	11.1	9.4
	5	5 56 "	− 28	11.3	9.3
	7	4 19 "	+ 9	11.6	9.2
	7	6 34 P. M.	− 42	11.9	9.0
	11	5 17 "	− 76	12.9	9.3
	12	10 15 A. M.	+ 15	13.2	9.3
	13	3 29 P. M.	− 46	13.6	9.4
	16	12 16 A. M.	− 7	14.4	9.4
	19	1 39 "	+ 32	15.7	9.4
	21	1 31 "	+ 80	16.8	7.0
	21	2 26 "	+ 68	16.8	7.7
	21	3 08 P. M.	+ 42	17.5	9.3
	24	9 56 "	+ 49	19.5	8.5
	26	8 38 A. M.	+ 58	21.0	8.6
		STARS NEAR MARS.			
May	10	2 46 P. M.	− 61	9.9	9.1
	12	5 18 A. M.	+ 1	10.3	9.5
	15	3 34 "	− 52	10.7	8.3
		STARS NEAR JUPITER.			
May	23	9.5 P. M.	− 16	1.2^h	6.0
		STARS NEAR SATURN.			
May	9	4.8 P. M.	+ 71	4.6^h	9.5

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	Angle f'm N pt. °	EMERSION Washington M. T. h m	Angle f'm N pt °	Duration. h m
May 1	c Geminorum	6	10 22	47	10 50	346	0 28
13	A Ophiuchi	5	9 22	149	10 16	253	0 54
13	38 Ophiuchi	7	10 23	119	11 39	282	1 16
29	λ Cancri	6	10 22	86	11 08	308	0 46

Phases and Aspects of the Moon.

		Central Time. d	h m
First Quarter	May	3	1 12 P. M.
Apogee	"	8	11 18 P. M.
Full Moon	"	11	4 59 P. M.
Last Quarter	"	19	8 53 A. M.
Perigee	"	24	10 30 A. M.
New Moon	"	25	11 49 P. M.

The Great Sun-Spot.—The great Sun-spot group of February reappeared on the east limb of the Sun about March 3. Our first photograph was obtained March 5. The group was so changed as to be unrecognizable, there being but four rather inconspicuous spots, surrounded by a large area of brilliant faculæ On subsequent dates one of these spots developed so that it was quite conspicuous. It had two umbræ somewhat like the principal ones in February. They changed considerably from day to day and it was impossible to identify them with certainty with the two spot centers whose positions we determined in February. The following are the measures of photographs taken at Goodsell Observatory:

		Central Time. h m	Spot Center A. Long. °	Lat. °	Spot Center B. Long. °	Lat. °
March	5	12 29	251.4	− 26.8		
	7	2 50	251.5	− 27.6	250.4	− 29.0
	8	12 46	251.2	− 27.9	248.7	− 29.3
	10	12 54	251.8	− 28.2	251.2	− 27.5
	11	1 52	251.0	− 28.4	250.3	− 28.3
	12	4 53	251.7	− 28.3	250.0	− 28.1
	14	9 39	251.9	− 27.8	249.2	− 27.9
	15	2 05	251.9	− 28.5	249.4	− 29.1

Three New Asteroids, Nos. 324, 325 and 326. A planet of the 11th magnitude was discovered by Palisa at Vienna Feb. 25.5454 Gr. M. T.: R. A. 10^h 26^m 17.4^s: Decl. + 7° 40′ 35″.

A planet of the 12th magnitude was discovered by Wolf at Heidelberg March 18.4048: R. A. 11^h 06^m 40.6^s; Decl. + 4° 44′ 49″.

A planet of the 11th magnitude was discovered by Palisa at Vienna March 19.3900: R. A. 13^h 27^m 00.0^s; Decl. + 9° 55′ 09″. Daily motion west 16′, south 3′.

New Asteroid No. 327—A planet of the 13th magnitude or fainter was discovered by Charlois, at Nice, March 22.5190: R. A. 12^h 41^m 13.3^s; Decl. — 7° 15′ 26″; Daily motion 15′ west, 5′ north.

Professor J. K. Rees' Astronomical Lectures.—Professor Rees of Columbia College, New York City has recently delivered a course of lectures on Astronomy, at Yonkers, N. Y., of which the daily papers of that city speak very favorably.

COMET NOTES.

March has been the banner month for discovery so far this year. Four new asteroids and two new comets have been discovered and Winnecke's periodic comet has been rediscovered at its sixth (observed) apparition.

Discovery of Comet b 1892 (Swift). On the morning of March 7, at $5^h\ 10^m$, while seeking for comets with my $4\frac{1}{2}$-inch telescope, I ran upon what at first sight, from its general appearance, I was sure was a comet. After some unusual delay, the 16-inch glass was turned on the object, but advancing daylight prevented the getting of its place with desired accuracy. Fortunately I had at 3 o'clock set my automatic R. A. circle to the R. A. of the meridian, and the following is the position read from it: $18^h\ 59^m$, the Decl. circle recording $-30°\ 20'$. It is possible that it is Brook's comet of 1886, though its great southern declination and its brightness both argue against the supposition. For a telescopic comet it exceeds in size and brilliancy any I have ever seen.—*Astronomical Journal No. 258.* LEWIS SWIFT.

Mr. Barnard writes that this comet is easily visible to the naked eye even in full moonlight. At Northfield we obtained observations of its position on the mornings of March 8, 14, 16, and 21 but did not try to see it without the telescope. There has been very little change in brightness. The nucleus became invisible each morning at almost exactly 6 o'clock central time or $5^h 47^m$ local time. The coma was brightest on the sunward side and there was a trace of a "fan." The tail was broad and about 1° in length.

The following observations are at hand:

	Greenwich M. T.	App. α h m s	App. δ ° ′ ″
Wilson,	1892 Mar. 8.0005	19 03 15.8	−30 34 48
Barnard,	8.0399	19 03 25.3	−30 32 53
Frisby,	11.9487	19 22 14.8	−27 18 48
Wilson,	13.9887	19 31 49.4	−25 26 33
Wilson,	15.9933	19 41 03.0	−23 34 45
Wilson,	20.9872	20 03 16.5	−18 41 00

Elements of Comet b 1892 (Swift)—Preliminary elements have been calculated by Rev. Geo. M. Searle, of the Catholic University at Washington, and by Miss F. E. Harpham and Mr. A. G. Sivaslian, students in Goodsell Observatory:

	Searle.	Harpham and Sivaslian.
$T =$	1892, April 26.99 Gr. M. T.	1892, April 7.74 Gr. M. T.
$\omega =$	81° 33′ (1892.0)	26° 09′ (1892.0)
$\Omega =$	237 34 (1892.0)	240 55 (1892.0)
$i =$	64 29 (1892.0)	38 54 (1892.0)
$q =$	0.5891	1.0185

Mr. Searle's elements depend upon the observations of Barnard March 8, Frisby March 11, and one by himself, March 12; those by Miss Harpham and Mr. Sivaslian depend upon the observations by Barnard, March 8, and Wilson, March 13 and 15. These latter elements represent the observations fairly well.

Re-discovery of Winnecke's Periodic Comet.—This comet was observed at Vienna March 18.4041 in R. A. $12^h\ 43^m\ 27^s.5$; Decl. $+30°\ 35'\ 38''$. The corrections to the ephemeris given in the February number of ASTRONOMY AND ASTRO-PHYSICS are thus -4^s in R. A. and $+9.8'$ in Decl. We have looked for this comet twice, since its discovery, with the 16-inch telescope but were unable to see it.

Discovery of Comet d 1892 (Denning).—A very faint comet was discovered by Denning in England, March 18.500 in R. A. 22^h 44^m; Decl. 59° 00′. Its daily motion was stated as north preceding, 50′. This comet was observed by Spitaler at Vienna, March 19.4338; R. A. 22^h 46^m 47.1^s; Decl. + 59° 17′ 43″. Cloudy weather prevented us from looking for this comet until March 24, when we failed to find it.

Search Ephemeris for Comet 1867 II. (Tempel's Periodic Comet.)

[Continued from page 250.]

Perihelion = April 3.5.

1892		R. A. h m	Decl. ° ′	log r	log Δ
May	5	18 24.6	− 23 46.0		
	10	18 25.9	24 22.4	0.3208	0.0984
	15	18 26.4	25 01.8		
	20	18 26.0	25 42.9	0.3231	0.0776
	25	18 24.7	26 24.2		
	30	18 22.7	27 06.2	0.3260	0.0634
June	4	18 20.0	27 47.7		
	9	18 16.7	28 29.6	0.3294	0.0562
	14	18 13.0	29 10.1		
	19	18 09.0	29 50.8	0.3332	0.0575
	24	18 04.9	30 32.0		
	29	18 01.1	− 31 13.0	0.3375	0.0645

		Perihelion = March 24.5		Perihelion = Apr. 13.5	
		R. A. h m	Decl. ° ′	R. A. h m	Decl. ° ′
May	10	18 50.6	− 25 06	17 59.6	− 23 17
	20	18 52.6	26 23	17 57.8	24 36
	30	18 51.1	27 48	17 52.8	25 59
June	9	18 46.6	29 15	17 45.8	27 20
	19	18 39.6	− 30 39	17 37.8	− 28 34

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 251.]

		Perihelion, March 1.			Perihelion, March 31.		
		R. A. h m	Decl. ° ′	Light.	R.A. h m	Decl. ° ′	Light.
May	10	21 56.5	− 25 26	0.17	20 42.4	− 29 44	0.53
	20	22 16.3	− 25 38	0.17	21 03.8	− 31 42	0.52
	30				21 20.1	− 33 46	0.50
		Perihelion, April 30.			Perihelion, May 30.		
May	10	17 20.8	− 27 19	2.45	12 16.9	+ 11 16	1.47
	20	17 31.1	− 33 43	2.44	12 24.3	+ 4 52	1.45
	30	17 36.8	− 39 23	2.16	12 36.5	− 1 56	1.35
		Perihelion, June 29.			Perihelion, July 29.		
May	10	10 24.7	+ 24 29	0.35	9 26.5	+ 28 53	0.13
	20	10 39.8	+ 20 19	0.36	9 43.5	+ 25 58	0.13
	30	10 57.6	+ 15 46	0.37	10 03.3	+ 22 49	0.14

Brorsen's Comet.—In reply to Dr. Lamp's request to forward the publications of the results of my work on the orbit of Brorsen's comet, I would say that, at present, my computations are not finished, but as soon as they are, I shall be pleased to forward them for publication. GEO. A. HILL.

Elements and Ephemeris of Comet b 1892 (Swift).—The following elements and ephemeris of Swift's comet were computed by Mr. A. G. Sivaslian and Miss F. E. Harpham. The observations used were those by Barnard, March 8, and Wilson, March 13 and 20.

ELEMENTS.

$$
\begin{aligned}
T &= \text{April } 6.6868 \text{ Gr. M. T.} \\
\pi &= 265^\circ\ 29'\ 00'' \\
\omega &= \ \ 24\ \ 35\ \ 20 \\
\Omega &= 240\ \ 35\ \ 40 \\
i &= \ \ 38\ \ 40\ \ 43 \\
\log q &= 0.011252
\end{aligned}
\left.\vphantom{\begin{aligned}\pi\\ \omega\\ \Omega\\ i\end{aligned}}\right\}\text{Mean equinox } 1892.0 \qquad q = 1.02625
$$

Middle Place

$$d\lambda\ \cos\beta = -\ 5''$$
$$d\beta = -\ 4''$$

The equatorial co-ordinates are given by the following equations:

$$
\begin{aligned}
x &= r\,[9.923121]\ \sin\,(349^\circ\ 05'\ 41'' + v) \\
y &= r\,[9.999781]\ \sin\,(257\ \ 54\ \ 19\ \ + v) \\
z &= r\,[9.737957]\ \sin\,(345\ \ 06\ \ 41\ \ + v)
\end{aligned}
$$

The comet is moving north and east and will reach its maximum brilliancy early in April. It will continue to be visible, in the morning sky, through May and June.

EPHEMERIS.

Date		App. R. A. h	m	s	App. Decl. °	′	″	log Δ	log r	Br.
1892 Apr.	5	21	04	09.9	− 2	56	22	0.0274	0.0114	1.37
	6		07	55.3	1	53	50			
	7		11	38.8	0	51	45			
	8		15	20.3	+ 0	09	52			
	9		19	00.0	1	10	59	0.0336	0.0116	1.33
	10		22	37.8	2	11	36			
	11		26	13.8	3	11	39			
	12		29	48.0	4	11	05			
	13		33	20.3	5	9	53	0.0416	0.0136	1.27
	14		36	50.9	6	8	00			
	15		40	19.8	7	5	25			
	16		43	47.0	8	2	06			
	17		47	12.6	8	58	01	0.0512	0.0175	1.20
	18		50	36.5	9	53	10			
	19		53	58.7	10	47	31			
	20	21	57	19.3	11	41	03			
	21	22	00	38.3	12	33	46	0.0620	0.0230	1.11
	22		03	55.7	13	25	39			
	23		07	11.5	14	16	42			
	24		10	25.7	15	06	53			
	25		13	38.3	15	56	13	0.0735	0.0302	1.02
	26		16	49.3	16	44	42			
	27		19	58.7	17	32	19			
	28		23	06.6	18	19	05			
	29		26	12.9	19	05	01	0.0856	0.0387	0.93
	30		29	17.6	19	50	05			
May	1		32	20.8	20	34	18			
	2		35	22.4	21	17	41			
	3		38	22.5	22	00	15	0.0978	0.0484	0.84
	4		41	21.0	22	41	59			
	5		44	18.0	23	22	54			
	6		47	13.4	24	03	01			
	7		50	07.3	24	42	21	0.1102	0.0591	0.75
	8		52	59.6	25	20	54			
	9		55	50.4	25	58	41			
	10	22	58	39.7	26	35	43			
	11	23	01	27.4	27	12	00	0.1223	0.0706	0.67
	12		04	13.6	27	47	34			
	13		06	58.2	28	22	26			
	14		09	41.2	28	56	35			
	15	23	12	22.7	+ 29	30	04	0.1341	0.0828	0.60

NEWS AND NOTES.

The pressure upon us for space, this month, has led to an additional form of 16 pages in the present number. The four plates accompanying important articles are fine and helpful illustrations.

Subscribers and correspondents are requested to notice especially the announcements that are made on the last page of these notes. Careful attention to the directions there found will materially aid all interested.

United States Naval Observatory.—We have been much interested in the steps of progress taken during the last sixty days, pertaining to a change in the management of the United States Naval Observatory. To this end bills have been introduced into both branches of Congress, urging that the name of the Observatory be changed, and that the superintendency of it be placed in the hands of a skilled practical Astronomer. In support of this movement other useful, general work, in scientific circles, is going forward with perfect unanimity.

The Harvard College Observatory Time Service.—Not long ago, Professor E. C. Pickering, Director of Harvard College Observatory, published a brief historical statement of the Time Service of the Observatory which has been in operation since 1856. From this review of the work of that Observatory an extract is taken to show how other Observatories have suffered in a much greater degree, at the hands of ambitious Government officers aided by a single commercial corporation:

"One of the greatest advantages of the time-service to the Observatory has been that it kept before the public the practical value of astronomical work. Many thousands of persons who take no interest in work of a purely scientific character recognize the great financial value to the public of an accurate system of time. The Observatory desires to confer this benefit on the public, and it would be ready to do so even at a financial loss. But recently the time-signals of the United States Naval Observatory have been offered to the public at very low rates, through the Western Union Telegraph Company. This can the more readily be done since the expense of furnishing the time is borne by the people through a government appropriation, while the company has the largest facilities for the maintenance of telegraphic connections. The Harvard College Observatory is therefore relieved of this duty. If the public is to be the gainer, signals of equal accuracy and continuity must be furnished. Unfortunately, signals sent to a great distance are liable to frequent interruptions from trouble with the telegraph lines, and therefore secondary clocks must be used in each large city if continuous signals are to be distributed. These clocks must be constantly compared and corrected if great accuracy is to be attained, and it is still a question whether satisfactory results can be secured outside of an Astronomical Observatory. If the results prove unsatisfactory, however, the responsibility for trying the experiment will not rest upon this Observatory."

"In view of the facts stated above, it has been decided to discontinue the time-signals furnished by this Observatory after March 31, 1892. An earlier date would have been selected, but for the desire to give our subscribers sufficient time to make other arrangements for securing signals."

If one of the most able and judicious astronomers in America, who stands at

the head of one of the greatest Astronomical Observatories, speaks out thus frankly and forcibly for *cause*, what could others say who are in charge of smaller Observatories and who have depended chiefly on local support for their scientific work, if they cared to make their views known?

The New Star in Auriga Disappearing.—The new star is going the way of all temporary stars. It is invisible with an opera-glass or small telescope. On a photograph taken at Goodsell Observatory, March 23, with a camera and 2½ inch Darlot lens, exposure 30 minutes, the star made no impression whatever.

Mr. Thomas D. Anderson, the discoverer of this star, has written the following letter which was published in *Nature*, Feb. 18, 1892:

"Prof. Copeland has suggested to me that, as I am the writer of the anonymous postcard mentioned by you a fortnight ago, I should tell your readers what I know about the Nova.

"It was visible as a star of the fifth magnitude certainly for two or three days very probably even for a week, before Prof. Copeland received my postcard. I am almost certain that at 2 o'clock on the morning of Sunday, the 24th ult., I saw a fifth magnitude star making a very large obtuse angle with β Tauri and χ Aurigæ, and I am positive that I saw it at least twice subsequently during that week. Unfortunately, I mistook it on each occasion for 26 Aurigæ, merely remarking to myself that 26 was a much brighter star than I used to think it. It was only on the morning of Sunday, the 31st ult., that I satisfied myself that it was a strange body. On each occasion of my seeing it, it was slightly brighter than χ. How long before the 24th ult., it was visible to the naked eye I cannot tell, as it was many months since I had looked minutely at that region of the heavens.

"You might also allow me to state for the benefit of your readers that my case is one that can afford encouragement to even the humblest of amateurs. My knowledge of technicalities of astronomy is, unfortunately, of the meagerest description; and all the means at my disposal on the morning of the 31st ult., when I made sure that a strange body was present in the sky, were Klein's "Star Atlas," and a small pocket telescope which magnifies ten times." H. C. W.

Astronomical and Physical Society of Toronto.—A copy of the Transactions of this Society for the year 1891, has recently been sent us through the kindness of the corresponding Secretary, Mr. Lumsden. This is a neatly printed volume of 80 pages, with a lithographed drawing of Jupiter as frontispiece. The list of papers read at the meetings, abstracts of which are given for the most part, shows that the people of Toronto are very much interested in astronomy and physics and are doing creditable work. At the end of the volume is a list of the principal sidereal phenomena for the year 1892. H. C. W.

On the Possibility of seeing Meteors from Comet 1882 I.—Permit me to call attention to the fact that the Earth passes near the ascending node of comet 1882 I on April 15, the approach being a rather unusually close one. The Earth passes outside the comets' node by 0.03 of the Astronomical unit, or about 3 million miles. This comet was a bright and large one, and, allowing for the lateral spreading of meteors in their orbits, it is quite possible that the Earth might attract some of them into its atmosphere. The radiant point is 356.9° in R. A. and —14.°4 in Decl. O. C. WENDELL.

Harvard College Observatory, March 21, 1892.

Distribution of the Moon's Heat.—The February number of the Monthly Notices of the Royal Astronomical Society is an excellent one. It gives this favorable summary to Professor Very's recent researches on the distribution of heat on the Moon's surface: "The maximum for light is more pronounced than that of heat, so that the visible rays form a much larger proportion of the total radiation at the full than at the partial phase. Next, the heat areas are eccentric, having their greatest extension towards the west; the diminution of the heat in the third quarter of the lunation is slower than its increase in the second, and, lastly, there is a fair agreement between Mr. Very's results and those of Lord Rosse, although so differently obtained. Thus the result of Dr. Copeland obtained in 1870, that the greatest heat was attained before the full, is confirmed by the present series of observations."

"Mr. Very's researches open a new field, as previous investigations have dealt with the radiation of the Moon as a whole, whereas his method deals with that from numerous small portions of its disc under various conditions of phase, thus affording much additional information of a kind entirely new."

Strassmaier and Epping's Researches on Babylonian Astronomy.—In the last number of *Monthly Notices* will be found an account of the labors of Strassmaier and Epping in deciphering the Assyrian texts pertaining to Babylonian Astronomy. The labors began more than ten years ago, and the results already reached have established in great measure the system of astronomy of the Babylonians regarding their method of calculating and predicting the new Moon, the determination of the dates of the era of the Seleucidæ in Julian style, the explanation of the lunar and planetary calendars, the mode of prediction used therein and the publication of several lunar and planetary tables of observation. Under the head of chronological results the following facts are given:

"The commencement of the eras of the Seleucidæ (S. E.), and of the Arsacidæ have been fixed with a certainty which is based upon the calculation of eclipses contained in the Lunar Calendars. The years of the Seleucidæan eras were luni-solar; their months lunar, sometimes of thirty, at others of twenty-nine, days. They employed intercalary months, but according to what law is yet unknown. The year commenced with the month Nisan, which fell about the spring equinox. The five following dates have been determined by Epping:

1 Nisan	188 S. E	= April	4 —	123	J. E.
"	189 "	= March	25 —	122	"
"	190 "	= April	12 —	121	"
"	201 "	= "	10 —	110	"
"	202 "	= March	30 —	709	"

Hence the Seleucidæan era began in the year — 310 of the Julian era, and that of Arsacidæ in the year — 246. The civil day of the Babylonians began at sunset, and the division of the day into twenty-four hours was in use among them. But their astronomers, as is evident from the calculating tables, besides using a division of the day into 360 time-degrees, referred its commencement to the midnight following the beginning of the civil day."

The entire account indicates that these men are engaged in the successful prosecution of a most useful piece of scientific work.

M. Camille Flammarion's Popular Lectures in Paris.—By kindness of American friends, resident in Paris, we have been favored with copies of the *New York Herald* (Paris edition) containing brief accounts of the popular lectures on Astron-

omy recently given by the distinguished M. Camille Flammarion in that city. Two themes of his latest lectures were "Among the Stars" and "The End of the World." The Herald's account of the last is graphic indeed, and would be repeated here somewhat at length, if we could be sure that the reporter had correctly stated Flammarion's views. His references to Christ's sayings about the end of the world are noteworthy. There is but one quoted passage in this review. It is as follows: "I believe," said Flammarion, "that life is eternal, and as the world had a commencement so I expect that it will have an end. The transformation may come from any quarter. It may as likely begin in the middle of the great American continent, as in the middle of the Atlantic Ocean, or in Egypt, amid the Pyramids, as the center of England; but we scientists are forced to arrive at the conclusion that it will come about in the manner above described."

Note on the Lick Observatory Lunar Photographs.—In number 16 of the Publications of the Astronomical Society of the Pacific, a letter from Professor Weinek of Prague, was inserted because it afforded an "interesting proof of the value of the Lick Observatory Moon negatives when studied by an eminently competent eye." Professor Weinek said: "Neison has erroneously drawn the small crater which lies N. W. on the crater Thebit A on the outer wall. According to the negative (of Aug. 27, 1888) it lies on the inner wall." That is, Professor Weinek means Neison has drawn the small crater on the N. W. outer wall of the crater Thebit A.

As I possess excellent silver prints from the negatives of Aug. 15 and 27, 1888, I have examined them and also Neison's map for this small crater and have found that it doesn't exist. Neison certainly shows no such formation; Evidently Professor Weinek's "eminently competent eye" was somewhat at fault this time. But N. W. of Thebit A Neison has drawn a small crater on the outer wall of Thebit. According to the photograph of Aug. 15, this lies on the inner wall and in such a manner that it also must be considered as a feature of the floor of the crater (Thebit). The photograph of Aug. 27 does not show this small crater at all.

I wish to call attention to the erroneous way in which Neison, in his Map VI, has drawn the crater Pico D with reference to the three-peaked mountain Pico B. The photograph of Aug. 15, 1888, also shows a very distinct crater N. E. of Pico D which Neison does not show on this map. Yet, in Map IX, although these features are only introduced on the margin, they are all shown and shown nearly in their correct relative positions. A glance at the photograph of Aug. 15 suffices to show that Neison's representation of the ridge, a portion of which lies between Pico D and B, is utterly worthless as regards detail.

In Map IX, Neison draws two small craters south of the bright mountain Piton. Both of these are shown in the photograph of Aug. 27, and to the right of one of them (Piton a) by about that crater's diameter, I think I detect another crater. If so, it is not shown by Neison.

Another new feature seen in the photograph of August 27, is a fine crooked white line crossing Plato from N. E. to S. W., a very delicate object to the naked eye. It might be a fault in the lunar surface, perhaps. I also see a narrow white line beginning at the mountain Plato Pi and extending N. E. until it just skirts the north side of the crater Condamine B and passes beyond. The nature of this I am unable to guess, unless it is a defect in the photograph. These features are only referred to here in order that they may receive proper attention and study from some person with an "eminently competent eye." ROGER SPRAGUE.

Berkeley, California, Feb. 26, 1892.

Note on Double Stars.

θ Auriga = OΣ 545 is undoubtedly binary.

The following are recent measures:

	A AND B		
1892.164	349°.0	2″.59	3 — 8
.167	349 .1	2 .35	3 — 8
	A AND C		
1892.167	292 .9	46 .11	9
.184	293 .4	46 .59	9

The following are previous measures:

		A AND B		
1871.42	5°.6	2″.15	OΣ	7 *n*
76.45	1 .9	2 .17	De.	4 *n*
78.86	5 .8	2 .17	β	2 *n*
		A AND C		
1852.12	290.9	43.27	OΣ	
76.24	292.6	45.17	De	
79.41	293.3	45.51	β	

The Greenwich 10 year Cat. 1880 gives the proper motion A. R. = + 0ˢ.0037 N. P. D. = + 0″.078.

The companion of Σ 3002 was found to be a delicate double.

		A AND B		
	1890.909	203°.4	4″.11	8 — 10
	.964	204 .2	3 .83	
Mean	1890.94	203 .8	3 .97	
		B AND C		
	1890.909	213 .1	0 .60	10 — 11
	.964	218 .8	0 .75	
Mean	1890.94	215 .9	0 .67	

Prof. S. W. Burnham has communicated the following measures:

		A AND B		
	1891.540	201 .3	3 .77	7.8
	.562	202 .9	3 .80	8
	.575	202 .1	3 .83	8
Mean	1891.56	202 .1	3 .80	
		B AND C		
	1891.540	205 .2	0 .75	11 — 11.5
	.562	214 .0	0 .75	11 — 11.3
	.575	215 .6	0 .90	10 — 10.8
Mean	1891.56	214 .9	0 .80	10.7 — 11.2

G. W. HOUGH.

Archenhold's Bibliography.—In answer to your letter of Jan. 13, I reply that the astronomical bibliography was already begun in 1889, and that 1889 and 1890 are almost complete except a few English periodicals which were not accessible to me at that time in the Berlin libraries.

The plan is extensive. Throughout, there is regard for what is of interest to astronomers. With this purpose, there are four main divisions: general, astronometric, astro-physics and astro-mechanics. These main divisions fall into subdivisions, as follows: general, in 40; astronometric, in 82; astro-physics, in 98; astro-mechanics, in 32. In accordance with your wish, the manuscript of the plan lies subject to your order.

The celebrated publisher, Engelmann, in Leipzig, after mature consideration h as declared that there is absolutely no profit in publishing the work, and there fore declines to undertake it. In consequence, I negotiated through the astronomical Gesellschaft with Professor Bruns in Leipzig for the printing, and the Gesellschaft will be prepared, as soon as the edition of the zone-observations is somewhat farther advanced, to undertake the edition of the Bibliography. In case it should be necessary, I would willingly publish the Bibliography quarterly instead of yearly, and it appears to me not improbable that it will perhaps appear as a supplement to your publication, ASTRONOMY AND ASTRO-PHYSICS. I would also in any case, be prepared to furnish an abstract for your journal.

My farther purpose is to complete the Bibliography backward until it joins the Houzeau-Lancaster, although the latter would be brought out later than the first.

F. S. ARCHENHOLD.

Wolsingham Observatary.—From the report of 1891, by T. E. Espin, Director of Wolsingham Observatory the following paragraph is taken:

"The work of the Observatory has been much the same as in former years. As the Science of Astronomy widens, the greater the need of taking up one special line and working steadily at it. The sweeps for stars of the Third and Fourth Types have, therefore, been continued, and also the re-observation of Red Stars, published in the Red Star catalogue. During the year, 120 new Third Type Stars have been discovered, and one Fourth Type Star, bringing the total to 627; many of them are faint and difficult objects even with the large light-grasping power of the telescope and some doubt exists as to whether some of them may not be really of the Second Type. The year has been an interesting one in the records of the Observatory through the discovery of five variable stars. One is particularly interesting as discovering a star of Burton's, which has long been missing. Seven nights in the Autumn were given up to the observation of those stars on Dr. Wolf's photos of Cygnus, which showed much discrepancy in magnitude as compared with Argelander. In all, 171 stars were thus observed. As some doubt appears as to the number of Red Stars in the Perseus Cluster, it was carefully examined in December, and another Red Star added to the received number, making, in all, nine. The work of the Observatory has been much facilitated by the generous gift of Argelander's Charts by Mr. T. W. Backhouse. This has allowed of systematic zone work, and seven hours of zone $+55°$ had been examined by the close of the year. The charts were directly compared with the sky, and the stars which had anything remarkable in their spectra pencil marked in the Charts, thus saving the labor of circle readings, and assuring certain identification."

National Observatory at Athens—I have the honor to inform you that the Royal Government has placed me in charge of the National Astronomical and Meteorological Observatory of Athens.

The period of re-organization which we are experiencing does not permit us at present to take the active part which we desire in the great scientific movement in which your celebrated journal occupies so distinguished a place. But we hope that by means of the improvements which we are constantly seeking in our service, we will soon be in a position to contribute as much as possible by utilizing the beautiful sky of Athens, to the advancement of our science.

A regular publication of our astronomical and meteorological work is found in the plan which we hope to realize, and which will enable us to establish scientific communications and to follow the great progress of our science.

I hope that you are willing to materially aid us in our labor by sending us your journal. Our Observatory will be greatly favored if you are willing to enrich our library by a complete collection of the works issued by you, and your celebrated journal. DEMETRITS EGINITIS, Director.

Dr. Bœddicker's Drawing of the Milky Way.—We have just received a beautifully executed lithographic copy of a drawing of the Milky Way made by Dr. Otto Bœddicker, astronomer at the Earl of Rosse's Observatory at Birr Castle, Parsontown, Ireland. This drawing shows the Milky Way from the north pole to 10° of south declination, as it appeared to Dr. Bœddicker's eye, and shows a wonderful amount of detail. It was begun in Oct., 1884, and required five years of very careful and difficult observation. The drawing could only be made in small sections, but the sections were drawn repeatedly, and varied in such a way that each overlapped several others, thus enabling the observer to compare the scales of light intensity of different nights. After the whole visible galaxy had been gone over thus in small sections, these were combined into a composite picture of the whole.

We congratulate Dr. Bœddicker on having completed so successfully his long and arduous task and upon having his work so skilfully reproduced, as it has been done by Mr. Wesley. It will be very interesting to compare this work with the photographic pictures of the Milky Way which are being obtained. H. C. W.

The Mexican Meteorites by J. R. Eastman.—We have only lately seen Professors J. R. Eastman's paper on "The "Mexican Meteorites" which was read before the Philosophical Society of Washington, D. C., Jan. 2, 1892. It was published last month. In that paper is a brief description of twenty-four of these meteorites. A table showing the designation of these masses and their respective weights is given below:

	Tabulated Weights of the Mexican Iron Meteorites.	*Kilograms,*
1.	The Bonanza masses (estimated at least 15 tons)	13,600
2.	The Butcher masses	1,699
3.	The Santa Rosa mass	63
4.	The "Couch" meteorite	114.3
5.	The Fort Duncan mass	44.1
6.	The Potosi mass (estimated)	91
7.	The Cerralvo mass (estimated)	136
8.	The Casas Grandes mass (estimated at 5,000 pounds).	
9.	The Centennial Exhibition mass, probably same as No. 8 (estimated)	1,134
10.	The Presidio del Principe masses, no weight known.	
11.	The Huejuquillo masses, San Gregorio	11,560
	" " Concepcion	3,130
	" " Chupaderos	15,600
	" " "	9,290
12.	The Ranchito mass, measures 3.65×20×1,5 meters.	
	" " (estimated)	40,800
13.	The La Plata mass	124.7
14.	The Guadalupe masses	46.4
15.	The Cacria mass	41.4
16.	The Mezquital mass	7
17.	The Bella Roca mass	33
18.	The Catorce masses, 576, 4.5, 41.7 kilograms	622.2
19.	The Charcas mass	780
20.	The Zacatecas mass	907
21.	The Toluca mass (estimated)	275
22.	Specimens from Los Amutes and Cuernavaca (no weight given)..	
23.	The Yanhuitlan mass	421
24.	The Caparrosa mass, 341 grams	0.3
	Total	100,519.4

Queries for Brief Answers.

7. I read in Steele's Astronomy, "It has been recently shown that the equator is not a perfect circle, but is somewhat flattened, since the diameter which pierces the meridian 14° east of Greenwich is two miles longer than the one at right angles to it." How is this explained? What is the cause? M. H.

8. What units of time and distance are used in applying Kepler's Third Law to the motion of the Moon? E. L. E.

9. How can Newton's method of discovering the law of gravitation be exhibited to a class of unprofessional persons? E. L. E.

Answers to Queries.

Query No. 3 (p. 255).—In reply to the question of G. I. H., "how far ahead have eclipses been predicted, and where can I obtain a list," I would call his attention to the 52nd vol. of the Memoirs of the Imperial Academy of Sciences of Vienna, which is the late Professor Appolzer's great work upon the past and future eclipses of the Sun and Moon.

The volume contains the necessary data for predicting 8,000 Solar and 5,200 Lunar eclipses, and covers the intervals from — 1207 to + 2161 or 3368 years. As this volume is very valuable, I doubt if it will be found in many of the libraries in the country.

We have it in our library, and if G. I. H. will address me stating what eclipses he desires, I will be pleased, with the permission of the superintendent, to give him the dates of such future eclipses as he may desire. GEO. A. HILL.

Naval Observatory, Washington, D. C.

Query No. 4 (p. 255).—The belief that Mercury rotates on his axis in the same time that he completes a revolution around the Sun rests almost wholly on the observations of Schiaparelli at Milan. Observations of Mercury's surface markings are so extremely difficult that no one has yet satisfactorily verified Schiaparelli's conclusions. The answer, therefore, to this query must be non-committal.

Query No. 6 (p. 255).—Answers have been received from Rev. Edward Brown, of Yankton, S. D., and F. Bradbury, St. Augustine, Fla. The expression, "The undevout astronomer is mad," is found in Young's "Night Thoughts," Night 9, about line 500.

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